

PROCEDURE HANDBOOK
SURFACE PREPARATION AND PAINTING OF TANKS
AND CLOSED AREAS

SEPTEMBER 1981

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IN COOPERATION WITH .
AVONDALE SHIPYARDS, INC.

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FOREWORD

This research project was performed under the National Shipbuilding Research Program. The project, as part of this program, is a imperative cost shared effort between the Maritime Administration and Avondale shipyards, Inc. The development work was accomplished by Complete Abrasive Blasting systems, Inc. under subcontract to Avondale Shipyards. The overall objective of the program is improved productivity and, therefore, reduced shipbuilding costs to meet the lower Construction Differential Subsidy rate goals of the Merchant Marine Act of 1970.

The studies have been undertaken with this goal in mind, and have followed closely the project Outline approved by the Society of Naval Architects and Marine Engineers' (SNAME) Ship Production Committee.

Mr. James A. Giese, of Camplete Abrasive Blasting Systems, served as Project Manager and Ms.polly Medlicott as technical writer. On behalf of Avondale Shipyards, Inc., Mr. John Peart was the R & D Program Manager responsible for technical direction, and publication of the final report. Mr. Ben Fultz of Offshore Power Systems performed editorial services. Program definition and guidance was provided by the members of the 023-1 Surface Preparation Coatings Committee of SNAME, Mr. C. J. Starkenburg, Avondale Shipyards, Inc., Chairman.

Also we wish to acknowledge the suppxt of Mr. Jack Garvey and Mr. Robert Schaffran, of the Maritime Administration. Special thanks are given to the numerous suppliers listed below for their valuable contribution of information (see Annex A for complete address ad telephone numbers).

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Executive Summary

A desperate need exists in shipyards for the proper planning and execution of surface preparation and coating operations in tanks and other enclosed areas. Abrasive blasters and painters are exposed to high concentrations of dust and hazardous organic vapors. Other shipyard personnel are exposed to the potential dangers of explosion and fire.

Another aspect of the need for better planning concerns the inefficient utilization of capital, manpower and material assets. As an example, many extra manhours of labor are consumed in tank surface preparation operations because the abrasive blaster, when operating in tanks, just cannot see what he is blasting due to dust accumulation. Also, many square feet of painted surface are lost due to solvent entrapment during cure resulting in catastrophic premature paint failure.

Until the publishing of this report no single document existed which could be used by shipyard planners to effectively, efficiently and safely plan painting operations in confined areas. The information contained within this handbook includes:

- Identification of the requirements and related problems associated with surface preparation and painting of tanks and enclosed areas.
- Identification of personnel exposure limits
- Identification of monitoring equipment for measurement of fume and dust concentrations and ventilation rates.
- Identification of maximum allowable concentrations and ventilation requirements for abrasive blasting and coatings application
- Identification of suitable ventilation and abrasive blast equipment for shipyard operations.

In addition to the above points, a practical model for upgrading the blast-paint department is offered. Throughout the course of this study, emphasis was placed on increasing productivity and improving environmental conditions. These points can be achieved through a management sponsored systematic program of planned improvements based on "recommendations within this report.

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SECTION 1

Conclusions

1. Conclusions

1.1 Background

The advent of huge, complex ocean-going vessels represents millions of dollars in capital investment. Corrosion prevention through blast-cleaning and painting is essential for protecting the value of these ships as capital assets and for prolonging the productive life of the vessels. Yet, for the most part, few guidelines exist for planning critical protective coatings (painting) operations during new construction, especially in high performance areas, such as ballast tanks and enclosed areas.

Without exaggeration the blast-paint operation at sane shipyards can be characterized as the dirtiest, most disorganized, wasteful and even dangerous area in the yard. These conditions many times result from a lack of guidance concerning basic principles and apparent lack of knowledge concerning available technology and equipment. The net result is a staggering wastage of manpower, materials, and time.

An attempt to dispense with in-house painting operations by sub-contracting blast-paint operations only provides a short term solution, since responsibility for coating failures or production delays ultimately rests with shipyard management.

The only possible long-term solution to these problems is to approach the surface preparation and coatings operation as a unified system. An experienced professional manager, using a systems approach to planning and Coordination of the total program, can:

- Modernize equipment
- Reduce dependency on other services
- Improve environmental renditions

The task of converting the blast-paint section into a profitable, productive and clean department must become a high priority for managers of U.S. shipyards. Economical modernization of this operation can be accomplished by otherwise successful companies. Clearly, management plays a critical role in the development of a professional, efficient, surfaces preparation and coatings department.

1.2 Project Results

This project achieved the defined objective of creating a procedural Handbook detailing ventilation rates and procedures required for the surface preparation and painting of tanks and enclosed areas. This accomplishment is a step toward solving the problem areas discussed above. The handbook on Surface Preparation and Painting of Tanks and Enclosed Areas provides a tool which can be used by shipyard personnel to:

- Reduce labor hours for both blast-paint operation and for support services and equipment.
- Write procurement specifications for capital equipment procurement
- Reduce worker exposure to hazardous conditions
- Reduce facility and equipment losses
- Plan more competitive painting operations
- Reduce catastrophic paint failures
- Reduce interference between crafts during construction

The net result will be a savings in dollars expended to produce ships.

1.3 Recommendations

1.3.1 Blast-Paint Department

Management should commit high-caliber, technically capable personnel to the program to insure competency, efficiency and quality at all stages of the operation. These personnel should include:

- A surface preparations expert trained in quality control to coordinate between the shipyard and the ship owner. This individual would also be responsible for the inspection of cleaned surfaces and for monitoring dust-collection and dehumidification systems.
- A coatings specialist (ideally a chemsit) to review coating specifications, oversee application, sample coatings both at delivery and on finished surfaces, and maintain Ongoing data records of the coatings performance under actual shipyard conditions. This individual would aid in the selection of appropriate coatings and preclude legal applications arising from coatings failure.
- An instructor for an in-house program to train employees in the use of blasting, ventilating, dehumidifying, painting and compressed-air drying machinery.

General, components of the blast-paint operation which should be carefully considered by management are:

- Development of an overall organizational plan
- Development of a program check list to include all equipment
- Standardization of procedures and inspection techniques
- Establishment of a comprehensiver equipment maintenance program

- Coordination of transportation, delivery and storage of materials, to include support logistics

In the drydock area, modifications might include such things as end-ramp access so that equipment could be moved in and out without a crane, an elevator or other personnel lifting system between dock and deck, increased electrical services and installation of a high-volume compressed air piping system. Such improvements would result in a marked reduction of down-time during the blasting and coating operation.

Finally, a carefully designed permanent installation is (see Section 7) practically a must for the efficient completion of major jobs. The essential elements of a properly designed facility are:

- Large, enclosed space providing protection from the weather
- Equipment to control ambient air renditions
- Adequate utility hook-ups for electrical, water, compressed air and other services
- Permanent, properly designed ventilation system
- State-of-the-Art abrasive blasting and handling machinery permanently installed for maximum output
- Railroad track located next to the shelter for materials and equipment transport. Section 7 discusses one way of establishing a well-organized operations base for large blasting and painting jobs.

1.3.2 Naval Architects and Marine Engineers

Naval architects and marine engineers must be aware of problems faced by the shipbuilding/ship repair industry and encouraged to incorporate design changes which facilitate construction activities. Some suggestions are:

- Constructing permanent scaffolding supports in tanks
- Placing permanent openings in bulkheads
- Providing larger, more conveniently located hatch or cargo covers on deck.

These changes could greatly improve materials and personnel access for future maintenance activities.

1.4 Cost Savings

By using the handbook published as a result of this study and by systematizing the blast-paint operations as recommended, shipyards should save 30% to 50% of blast-paint operational costs. Generally, cost-savings will result in the following areas:

- Reduction of support services required. By utilizing the proper equipment and by making recommended modifications to existing facilities, dependence on support services would be significantly reduced. Lost production time waiting on required services (cranes, air hookup, water, etc.) would be eliminated.
- Improvement of environmental conditions. Many costly problems and delays are caused by the messy, dirty conditions associated with the blast-paint operation. These include contaminated air, high worker turn-over, non-compliance with governmental health and safety regulation, disposal of wastes, and constant housekeeping.

- Recovery and reuse of abrasive. Specialized equipment can enable the department to utilize inexpensive abrasives for some jobs in addition to recovering and recycling more expensive abrasive--materials for other jobs. Reducing expenditure of rapidly consumed abrasives can add up to surprisingly large savings. (See Annex c).
- Improvement of quality. Catastrophic coatings failures can obviously result in enormous costs for shipyards. A systematic approach to the total blast-paint operation, using proper equipment, correct procedures and careful record-keeping will assist in avoiding premature paint failures.

1.5 Summary

Preparing surfaces of enclosed tanks for coatings, including necessary ventilation and air treatment operations, is but one part of the construction and repair of a ship. However, it must be recognized, that these operations are just as essential as those performed by fabrication, mechanical or other shipyard manufacturing departments.

The blast-paint department depends on many support services and a variety of specialized equipment to complete projects. Technology is available which can correct both the environmental and worker safety problems associated with abrasive blasting in shipyards. This technology can be expensive, but ignoring the problems will be more expensive.

It is recognized that there are many possible ways to solve existing problems or meet defined objectives. This report provides one proposed process by describing equipment and by outlining procedures which are now available to the modern shipyard.

SECTION 2

Use of the Handbook

2. Use of the Handbook

An attempt has been made to organize this handbook in such a manner as to the reading easy and data presentation logical. The discussion proceeds from ventilation through dust collection and dehumidification to abrasive blasting. Section 7 discusses a model abrasive blasting and Painting pier which utilizes the principals presented.

The sciences of ventilation, dust collection, dehumidification and abrasive blasting and painting are each extremely sophisticated engineering fields. This handbook will not qualify the reader as an expert in any of these disciplines, but it does present certain basic principles, that, then followed, will help assure a well planned operation.

The reader should follow the presentation as written. If dust collection and/or dehumidification are not deemed to be required, then these sections can be scanned. However, be forewarned that a simple statement that these operations are luxuries and not necessary without verification through actual measurement will lead to many disastrous experiences.

Each section of the handbook maintains a technical discussion followed by equipment selection. The technical discussion includes examples and sample calculations. In many cases, a simple substitution of different numbers, depending on job size, is all that is necessary to obtain required planning factors. The equipment selection discussion describes equipment characteristics. Knowing the calculated planning factors and equipment characteristics a lead to the proper equipment selection for a given blast-paint operation.

SECTION 3

Ventilation

3. Ventilation

3.1 Introduction

There are two primary proposes for ventilating tanks and enclosed areas :

- Operator health and safety
- Operator visibility

These purposes are accomplished by removal of contamination air from the space and replacement of fresh air to the space. Where dehumidification and/or dust collection is indicated, ventilation is the basic component of a total air treatment system.

3.2 Technical Discussion

The following sections present general guidelines for determining ventilation requirements. Later sections discuss the design of the air-handling system to meet specific ventilation objectives. Additional detailed design information is contained within Industrial Ventilation - A Manual of Recommended Practice. That manual, which is published by the American Conference of Governmental Industrial Hygienists and endorsed by the Sheet Metal and Air Conditioning Contractors National Association, can be obtained from the Committee on Industrial Ventilation P. O. Box 453, Lansing Michigan 48902.

3.2.1 Ventilation During Abrasive Blasting

The amount of ventilation required during blasting depends on the following four variables. Percentage figures indicate the relative importance in calculating requirements:

● Size of tank (cubic feet)	60%
● Number of blast operators	15%
● Amount of corrosion on tank surface	15%

- Dusting or breakdown characteristics of abrasive (see Annex B for discussion of Abrasives) 10%

Ventilation is measured in terms of the volume of air movement over time, expressed as cubic feet per minute (CFM). A general guideline to providing an adequate environment in closed tanks would be one (1) complete air change every three minutes during the blasting operation. For example, a centerline or "Jumbo" tank with a 100,000 cubic foot capacity would require approximately 33,000 CFM of ventilation. Generally speaking, the greater the number of complete air changes, within reason, the **better** the resulting visibility in the tank.

Any one of the listed variables can significantly affect renditions inside the tank. For example, if the amount of dust being generated increases due to an excessively corroded tank surface and/or high abrasive breakdown, the supervisor can compensate for these conditions by changing one or more of the other variables. He may choose to decrease the number of blast operators, stop blasting and mechanically descale the tank to improve surface conditions or increase the amount of ventilation in the tank.

Unlike ventilation for paint or welding fumes, dry airborne dust created by abrasive blasting consists of relatively large particles. Since the particles can be seen, it is easy to monitor the success of the ventilation system in removing dust. A more detailed discussion of the ranges of abrasive breakdown characteristics, tank surface conditions and cleaned surface, standards will be described in Section 6, Annex B and Annex C.

The balancing of in-g and outgoing air is an important aspect of a ventilation system. If clean air is blown into the tank while muchless dirty air is being extracted, the result is air turbulence. The dirty air will subsequently be blown out any crack or opening in the tank. Similarly, the extraction of too much air relative to treated incoming air will result in improper dehumidification for condensation control. Air circulation balance is achieved then the total amount of incoming air, treated or un-treated, equals the total amount of air being exhausted. Conditions within

the tank, i.e., visibility, temperature or humidity, are thus maintained within a predictable, controlled range of efficiency and in accordance with safety requirements.

3.2.2 Ventilation During Painting

During painting operations in confined spaces, the air in these areas becomes laden with paint overspray and solvent vapor. The health and safety hazards presented by these conditions dictate that ventilation requirements be carefully calculated and subsequently monitored throughout the painting operation. To better understand the calculation of ventilation requirements, the following two definitions are necessary:

LOWER EXPLOSIVE LIMIT (LEL) : The lower limit of flammability or explosibility of a gas or vapor at ordinary ambient temperature expressed in percent of the gas or vapor in air by volume.

THRESHOLD LIMIT (TL) : The values for airborne toxic materials which are to be used as guides in the control of health hazards and represent time weighted concentration to which nearly all workers may be exposed 8 hours per day over extended periods of time without adverse effects.

Whereas regulatory requirements dictate that the ventilation volumes be sufficient to dilute solvent vapor to at least 25 percent of the lower explosive limit of the specific solvent being sprayed, 10 Percent is a more commonly used design factor which insures explosion and fire prevention under varying conditions. Table I contains ventilation volumes recommended to maintain solvent vapor concentratons below 10 percent of the LEL for representative tank volumes.

Table I

Ventilation Volumes Recommended To Maintain Solvent Vapor concentrations Below 10% of the Lower Explosive Limit.

<u>Tank Volume (Cu. Ft.)</u>	<u>Ventilation Volume (CFM)</u>
670	1,000
1,340	1,200
2,000	1,500
2,800	2,000
5,600	2,500
8,400	3,000
11,200	4,000
14,000	5,000
28,000	6,000
56, 000	10,000
84,000	15,000
112,000	20,000
168,000	30,000

In addition to safety factors, paint overspray can accumulate in enclosed tanks a blind workers with a dense particle fog. As in blasting, a relatively large volume of ventilation is necessary to maintain visibility and insure production efficiency.

It is important to note that the ventilation objective for abrasive blasting recommended in Section 3.2.1, (approximately one air-change every three minutes) will, in most cases, maintain solvent vapor concentrations below the required percentage of the lower explosive limit, as well as maintain good visibility. By using the guidelines contained within this handbook and by requiring workers to use respirators for painting, the same ventilation system can, in most cases, be utilized for both blasting and painting operations. It must also be remembered that ventilation requirements extend through the paint curing process.

The next two sections contain information on how to calculate LEL and TL. Table II contains current information on the LEL and TL for some common solvents. Since these limits are subject to change, the latest Federal Regulation should be used to calculate actual requirements.

3.2.2.1 Lower Explosive Limit

Most paints used in marine applications contain solvents which rapidly evaporate during spraying. As stated above, sufficient air must be extracted from the tank during painting to limit the concentration of the flammable solvents to no more than 25% of their lower explosive limit (LEL). The following example is used as a guide in demonstrating the principles involved in calculating required ventilation volumes for specific solvents. Toluene is selected as the representative solvent.

TABLE II
PROPERTIES OF COMMON SOLVENTS

Solvent	V _s Cubic feet of vapor per gallon of liquid at 70° F	Lower explosive limit (LEL) in percent by volume of air at 70° F	Threshold limit (TL) in percent by volume of air at 70° F
Acetone	44.0	2.6	0.1
Amyl Acetate (iso)	21.6	1.0	0.01
Amyl Alcohol (n)	29.6	1.2	
Amyl Alcohol (iso)	29.6	1.2	
Benzene	36.8	1.4	0.001
Butyl Acetate (n)	24.8	1.7	0.015
Butyl Alcohol (n)	35.2	1.4	0.01
Butyl Cellosolve	24.8	1.1	
Cellosolve	33.6	1.8	
Cellosolve Acetate	23.2	1.7	
Cyclohexanone	31.2	1.1	0.005
1,1 Dichloroethylene	42.4	5.6	0.01
1,2 Dichloroethylene	42.4	9.7	0.02
Ethyl Acetate	32.8	2.5	0.04
Ethyl Alcohol	55.2	4.3	0.1
Ethyl Lactate	28.0	1.5	
Methyl Acetate	40.0	3.1	0.02
Methyl Alcohol	80.8	7.3	0.02
Methyl Cellosolve	40.8	2.5	
Methyl Ethyl Ketone	36.0	1.8	0.02
Methyl n-Propyl Ketone	30.4	1.5	0.02
Naphtha (VM&P) (76° Naphtha) ...	22.4	0.9	0.01
Naphtha (100° flash) Safety Solvent - Stoddard Solvent ...	23.2	1.1	0.01
Propyl Acetate (n)	27.2	2.0	0.02
Propyl Acetate (iso)	28.0	1.8	
Propyl Alcohol (n)	44.8	2.1	0.02
Propyl Alcohol (iso)	44.0	2.0	
Toluene	30.4	1.4	0.02
Turpentine	20.8	0.8	0.01
Xylene (o)	26.4	1.0	0.01

Step One - Calculate Dilution Volume

The minimum amount of air required (dilution volume per gallon of solvent, in cubic feet) is obtained from the following equation, where. v_s is the cubic feet of vapor per gallon of solvent:

$$\text{Dilution Volume (cu. ft.)} = \frac{4 (100-\text{LEL})v_s}{\text{LEL}}$$

By selecting the appropriate values for LEL and v_s from Table 11, the dilution" volume required per gallon of toluene solvent is calculation as follows:

$$\begin{aligned}\text{Dilution Volume} &= \frac{4(100-1.4)30.4}{1.4} \\ &= 8,564 \text{ cu. ft. of air per gallon} \\ &\quad \text{of toluene}\end{aligned}$$

Step Two - Calculate Ventilation Volume

The required Ventilation Volume, in CFM, is found by multiplying the dilution vol- per gallon of solvent by the number of gallons of solvent evaporated per minute.

$$\text{Ventilation Volume (CFM)} =$$

$$\frac{\text{Dilution Volume (cu. ft.)} \times \text{gal. of solv. evap.}}{\text{gal ., of solvent} \quad \text{nun.}}$$

In our example, several workers are painting in an enclosed tank. They are applying toluene thinned paint at a combined rate of one gallon per minute (gpm). The paint is 40% solvent. The ventilation volume required to maintain the solvent vapor concentration in the tank safely below the LEL is calculated as follows:

$$\text{Ventilation Volume} =$$

$$\frac{8,564 \text{ cu. ft.}}{\text{gal . of Solv .}} \times 1 \text{ gpm paint} \times \frac{0.4 \text{ gal solvent}}{1 \text{ gal. paint}}$$

Ventilation Volume = 3,426 CFM (for toluene)

This ventilation volume is the minimum amount required to prevent the hazardous accumulation of flammable paint vapor.

The important factors to remember in determining the minimum ventilation **volume** to prevent explosions are:

- o The rate at which the paint is being applied (gallons per minute),
- o The amount of flammable solvent in the paint.

Tank size is not the controlling parameter. However, in larger tanks a greater amount of paint vapor would probably be generated due to the increased number of workers. Water-based painting requires almost no dilution volume to prevent explosion since these paints contain only 1% to 2% flammable solvents.

3.2.2.2 Explosive Vapor Detection

Two basic types of devices are used for explosive vapor detection. The type primarily used in the petrochemical industry is equipped with a heated catalytic element which is a possible source of ignition. As a safety measure, the element is protected by a fine mesh "Davy" screen that prevents flame propagation. Temperature of the heated element increases during exposure to a flammable atmosphere resulting in degradation of the sensing element. This characteristic necessitates frequent recalibration. When located in an area where paint can deposit on the sensor, an additional problem is created. The fine screen is readily clogged by paint which requires frequent removal for cleaning.

The detection principle recommended for shipboard tank applications uses a "cold sensor" which does not degrade with time or exposure to flammable vapors. No protective screen is used. The sensing element housing protects the instrument from physical damage. Sensitivity to paint solvents

is good, and the electronic alarm circuitry is simple and rugged. Since the detection element is not heated, power consumption is much lower than with heated element types. Portable battery-operated units can operate units several days before requiring recharging. See Figure 3.1. Simple construction and operation make this instrument suitable for fixed installation such as hood exhausts or ductwork which are not accessible for service and maintenance.

The use of these instruments and the determination of hazardous conditions should be restricted to individuals trained certified as 'Competent Personnel'.

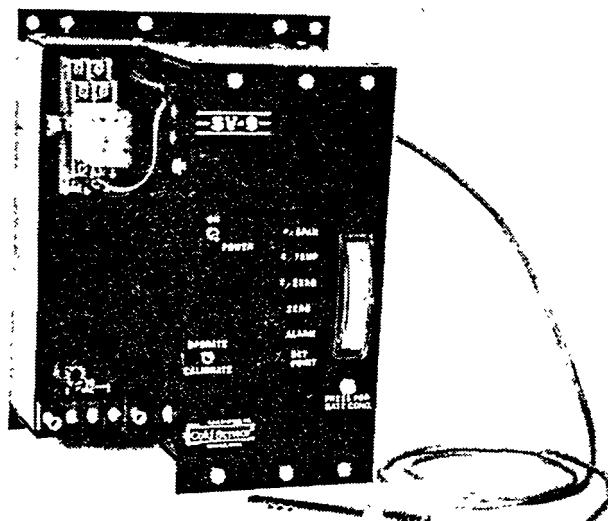


Figure 3.1: Explosive Vapor Detector

3.2.2.3 Threshold Limit

Limiting the flammable paint vapor concentration to 25% of the LEL is sufficient to prevent explosion hazard, but this concentration is too high -- for workers to breathe. Additional ventilation must be provided to reduce the paint solvent vapor concentration below the maximum levels allowed for workers on a routine basis. This concentration, called the threshold limit (TL), varies with the individual solvents used. A listing of the values for various solvents is contained in Table II. The dilution volume per gallon, of solvent required to maintain a concentration below the threshold limit is given by:

$$\text{Dilution Volume} = \frac{(100-\text{TL})}{\text{TL}} \frac{v}{s}$$

Where TL is expressed in percent by volume of air and vs is cubic feet of vapor per gallon of solvent.

The dilution volume for the threshold limit of toluene solvent can be calculated as follows:

$$\begin{aligned}\text{Dilution Volume} &= \frac{(100-0.02)}{0.02} 30.4 \text{ cu. ft.} \\ &= 151,970 \text{ cu. ft.}\end{aligned}$$

Referring back to the previous example in paragraph 3.2.2.1 the ventilation volume rate required to maintain the vapor concentration below the TL requires 60,790 CFM as calculated below:

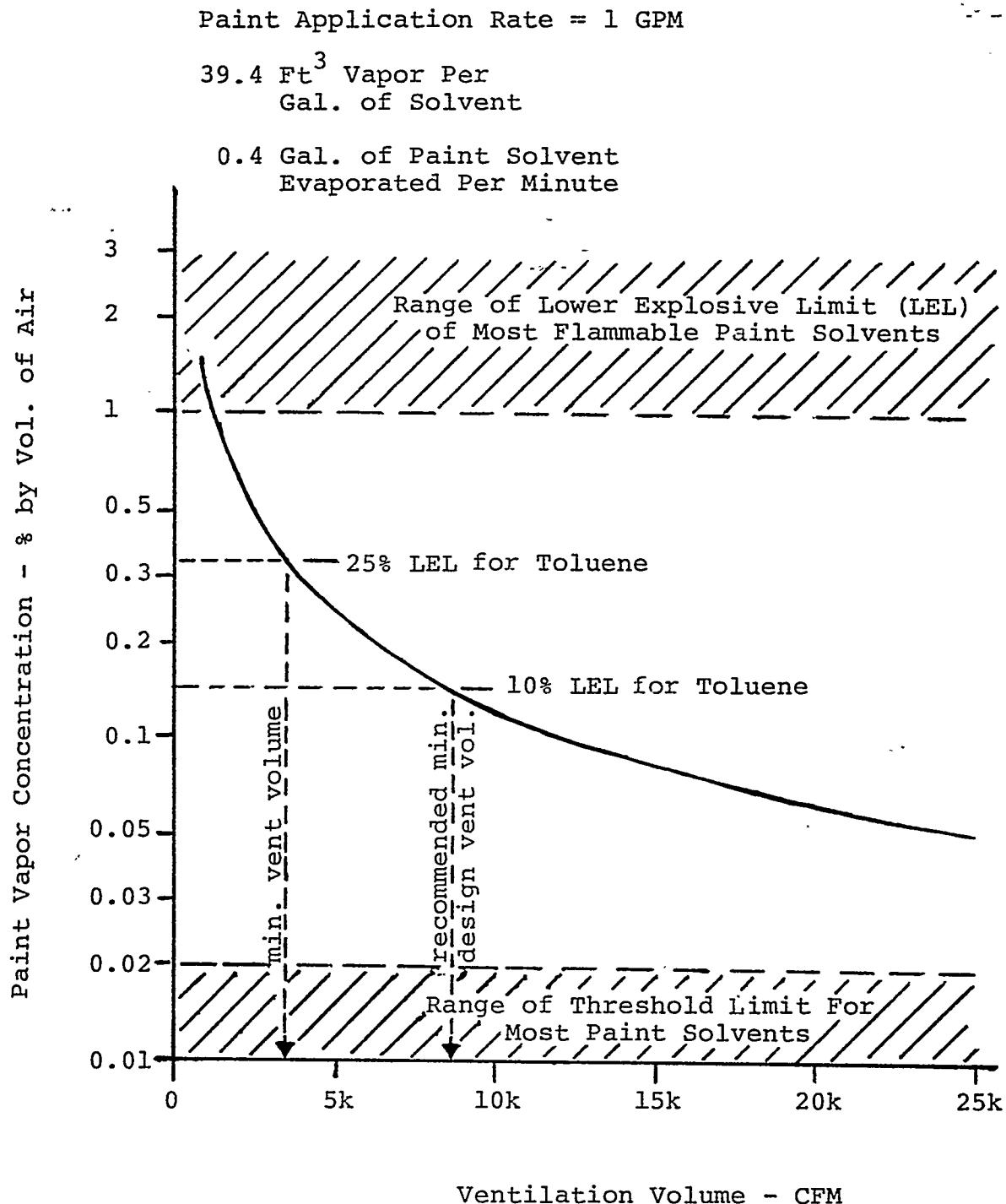
Ventilation Volume

$$\begin{aligned}&\frac{151,970 \text{ cu. ft.}}{\text{gal. of Solv.}} \times 1 \text{ gpm paint} \times \frac{0.44 \text{ gal. SOIV.}}{\text{gal. paint}} \\ &= 60,790 \text{ CFM (for Toulene)}\end{aligned}$$

This ventilation volume is the minimum required to maintain tank at an acceptable TL value.

Table III shows graphically the resultant paint vapor concentration for various ventilation volumes.

Table III - Paint Vapor Concentration versus Vent Volume



Maintaining the paint vapor concentration below the threshold limit requires extremely large volumes of fresh air, generally more than required for LEL maintenance or blasting operations. These volumes are difficult to provide due to air-handling equipment space limitations and cost, especially when dehumidification of the incoming air is necessary. An alternative solution is to require workers to use respirators when applying solvent-based paints in tanks. Another alternative is to limit the paint application rate to coincide with the required blasting ventilation volume. The same ventilation equipment can then do an effective job for both operations.

As stated earlier, water-based paints require only a small fraction (about 5%) of the ventilation volume required for solvent-based paints. This can be easily provided by the blasting ventilation volume.

3.3 Equipment Selection

Proper ventilation consists of equipment for moving air, equipment for directing or channeling the air and the efficient setup of this equipment. The following paragraphs discuss the principles of air movement and the proper selection of equipment necessary to effect efficient operations.

3.3.1 Fans

Fans are used to ventilate tanks by exhausting dirty air and/or by blowing in fresh air. Fans can be selected from a wide variety of sizes and types for different applications. The most important factors involved in determining the fan requirements are:

- Type of ventilation system required
- Amount of ventilation required
- Static pressure required
- Available space

Generally speaking, the objective is to choose a fan which provides required air volumes at proper static pressures with minimum horsepower and space utilization.

The two preferred types of fans for marine ventilation are duct-axial and centrifugal. See Figures 3.2 and 3.3. Compressed air driven fans are also commonly used by shipyards for general ventilation. However, air driven fans have low efficiency rating relative to power requirements and are therefore not suitable for moving the large volumes of air.

If the fan is to be used simply to ventilate the tank with ambient, untreated air, the duct-axial fan is the best choice. This fan is ideal for portable applications where large volumes of air are blown or exhausted through only 50 to 100 feet of ducting at low static pressure. Having a simple heavy-duty design, the duct-axial fan can be successfully operated in abrasive and dirty renditions. These fans are available in ranges of 10,000 to 50,000 CEM capacity. Due to their low static pressure ratings, they require minimum horsepower (3-10HP). In addition, duct-axial fans can be mounted either vertically or horizontally. Fans used for blast-paint operations should always be ordered with explosion-proof electric motor and spark-resistant construction. See Figure 3.4.

Centrifugal fans are capable of moving **large** volumes of **air** at high static pressure, and therefore, are used in conjunction with dust Collection and dehumidification systems. These fans can operate efficiently when connected to long runs of duct work. The increased static pressure capability of centrifugal fans result in increased horsepower ratings (25-250+HP). See Figure 3.5.

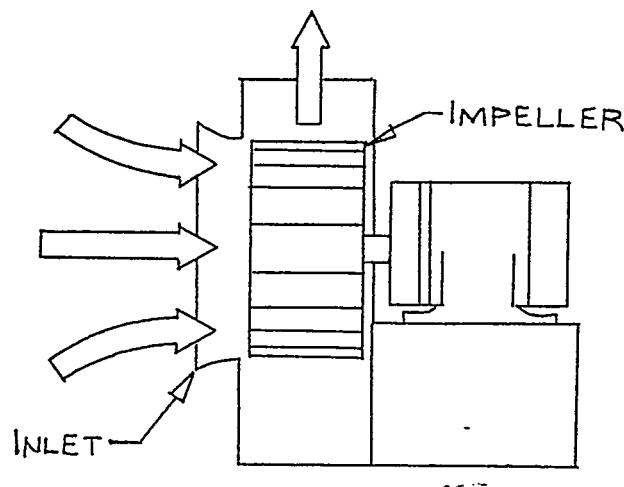


Figure 3.2: Centrifugal Fans - Air enters the center of the impellers in an axial direction and is discharged by the impellers radially through the fan outlet. It is generally used when high static pressures are required, above 10-15 inches water column.

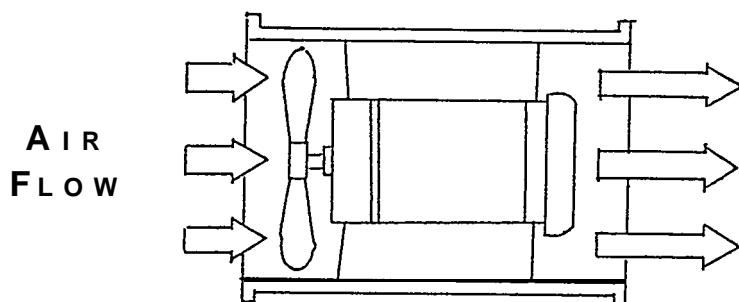


Figure 3.3: Axial Fans - Air enters and discharges in a straight line, parallel to - fan housing. It is generally used when a high volume of air is required, with the fan occupying the least amount of space.

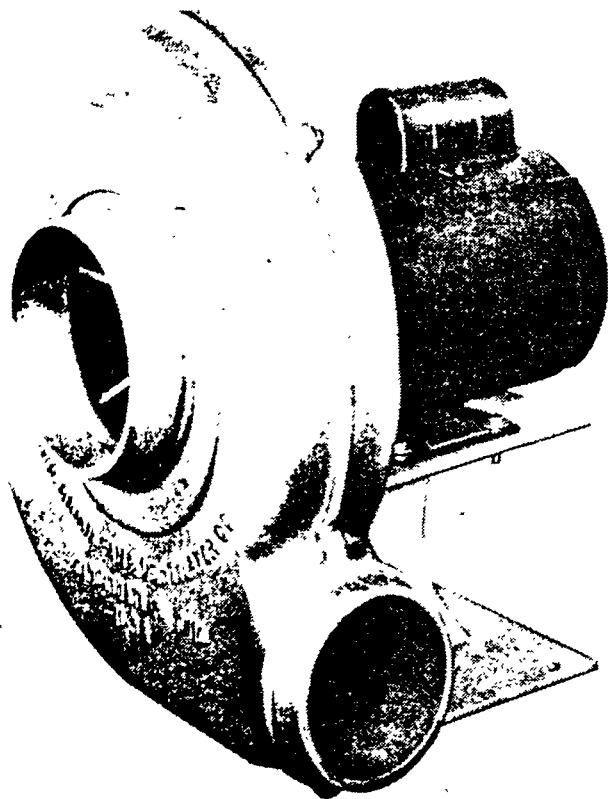


Figure 3.4:
Centrifugal Fan

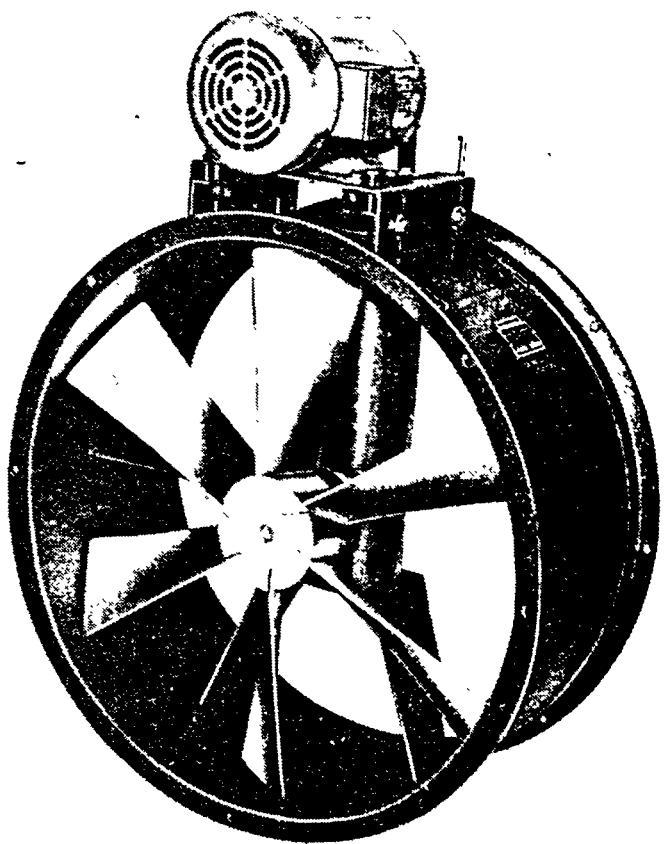


Figure 3.5:
Duct-Axial Fan

(Photos courtesy of Cincinnati Fan and Ventilator Company)

The required fan capacity can be calculated based on the size of the tank and the frequency of air changes necessary for adequate visibility. For example, an air change every three minutes in a typical 50,000 cu. ft. wing tank would require a fan capacity of 16,500 cfm. A 100,000 CU./ft² centerline tank would require a fan capacity of 33,000 CFM for the same air change frequency.

Fan capacity specifications are based on standard cubic feet per minute (SCEM) ratings. A SCEM represents one cubic foot of air at 70°F moving at a rate of one foot per minute. Air cooler than 70°F, and therefore denser, moves slower through a fan than warmer air. Also more horsepower is required to move a given volume at a given rate of cold air than of warm air.

Fans are designed for varying maximum static pressure potentials. Fan static pressure is required to overcome the resistance or friction of air moving through ducting. Figures 3.4 and 3.5

Static pressure requirements are calculated based on the size, length, and number of bends of the ductwork. Size is the cross-sectional dimension of the duct. To demonstrate the effect of bends and elbows on static pressure loss, one foot of 18" duct with a 90 deg. elbow has the equivalent resistance of approximately 28 feet of straight duct. Static pressure requirements are also increased by air passing through air treatment equipment. The static pressure requirement for a fan should be determined after the ducting and equipment layout for the ventilation system has been designed.

As an example, assume a fan must blow 9,000 CFM of air through a dust collection unit and 200 feet of 18" flexible ducting. The dust collector and the size and length of ducting each result in a 5" loss of static pressure for a total pressure loss of 10". Therefore the fan must have at least 10" of static pressure potential in order to maintain the 9,000 CFM required. See Table IV, for friction loss per 100 feet of various sized duct

In many cases, the rated fan static pressure may be sufficient to pull or push the air in the volume required. Generally, duct-axial fans used in single-purpose ventilation systems should have at least 1" static pressure capability, and preferably 2". Centrifugal fans used with dust collection equipment should be ordered with a minimum 12" static pressure rating.

In a well-designed, permanently installed air handling system, fans can be located at practically any distance from the tank and still operate efficiently. However, on jobs of short duration where portability and ease of installation are desired, the fan should be placed as close to the tank as possible in order to reduce the amount of ductwork required. Duct-axial fans can be ordered with special adapters enabling them to be mounted directly into 'Butterworth' openings and cargo hatches. Ideally the exhaust fan(s) should be placed over the 'Butterworth' opening(s) and ducted to two sides of the tank bottom. Fresh air should be blown into the tank through the cargo hatch. This arrangement will distribute the clean air uniformly through the tank and through the same passage operators use to enter and exit. If deck space is severely limited fans may be platform-mounted. If possible, fans should be isolated from communication areas because of high noise levels.

Installed fans should be checked periodically with a manometer. This device measures air flow. Measured reductions in air flow of an installed system can be indicative of worn parts such as impellers or destructed ducts .

In summary, the most flexible type of fan for ventilating tanks with ambient air is the duct-axial type with a rated capacity of 30,000-40,000 CFM, 2" of static pressure and a 4248" spark-proof case. Centrifugal fans with greater capacity for static pressures are primarily designed for use in air-treatment systems. Exact specifications will depend on the layout of the ductwork and/or treatment systems.

3.3.2 Ducting

Well-designed and Properly laid-out ductwork is essential to an efficient air handling system. Ducting design requires a thorough knowledge of requirements¹, accurate data on equipment performance specifications, accessibility, duct length and weight and volume of material to be moved i.e., abrasive dirt, solvent fumes, etc.

The two main areas of design criteria for ducting are:

- Sizing, including factors of CFM, static pressure, velocity requirements, and fan specifications.
- Layout, including type of job, ducting material, placement, and monitoring of the system.

The general objective for the ductwork design is a system of the smallest dimensions which combines the lowest practical static pressure requirements with sufficient velocity to transport the airborne materials.

3.3.2.1 Sizing

Sizing is the most critical consideration in selecting ducting because it determines, the thew the actual CEM, static pressure, and velocity of the air-f low in the finished ventilation system meets established design objectives.

For detailed information pertanining to duct design, consult Industrial Ventilation: A Manual of Recommended Practices

Four factors must be considered when selecting duct size:

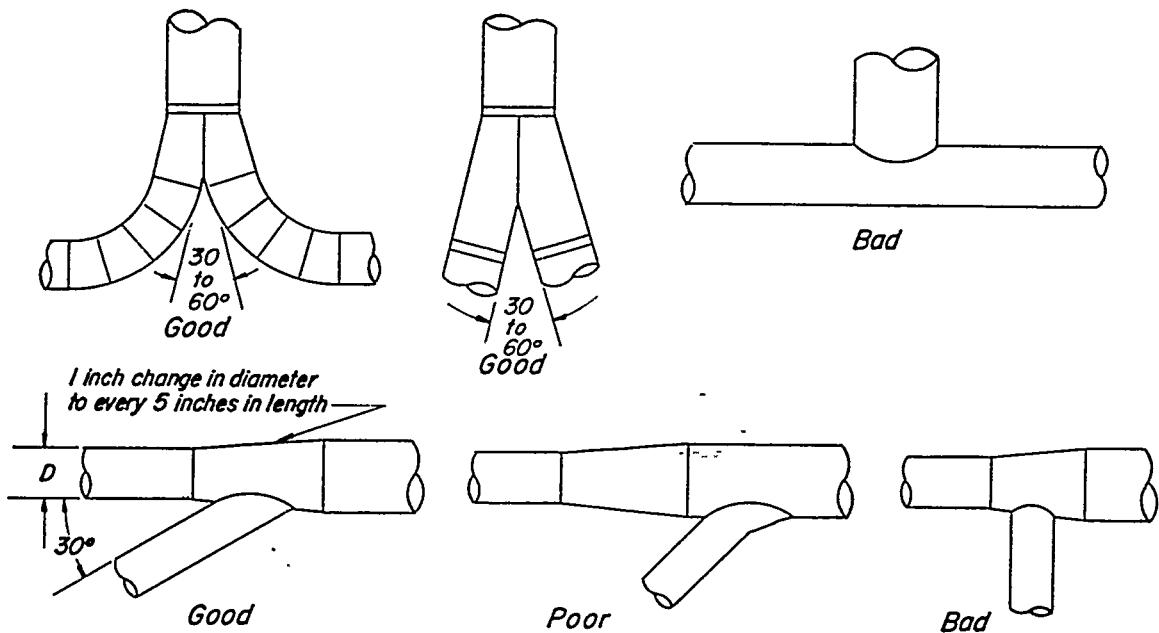
- Air volume in CFM
- Distance air is to be moved
- Static pressure limitation of available fans
- Air velocity requirements

With these four pieces of information, Table IV can be used to select the proper duct size.

As discussed earlier, air volume requirements are based on the size of the confined area and the characteristics of the material requiring venting. The distance the air is to be moved is simply the length of the ducting. Normally a fan which best meets the air volume requirements is selected from the existing capital inventory. The static pressure rating of the selected fan then becomes a design parameter which must be considered in the final ducting size selection.

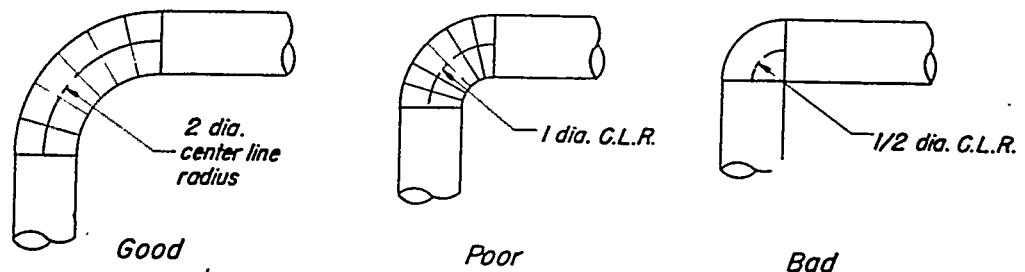
Velocity calculations are based on the characteristics of each type of material to be vented. If the duct is too large, resulting in a decrease in critical particle velocity along the length of the ducting the suspended material will fall out of the air-stream and build up in the bottom of the duct. As the duct fills, the ventilation capacity of the system is severely reduced and there is danger of the duct collapsing. As a rule, airborne dust resulting from abrasive blasting requires a critical particle velocity of 3,500 FPM.

Static pressure loss along the length of the ducting is directly related to the size (internal cross-sectional area) of the duct. If the duct is too small, the static pressure required to offset frictional losses may overload the fan capacity, resulting in a reduction of air volume moving through the system. It must be remembered that as static pressure requirements increase, more energy (HP) is required to operate the system. Excessive energy requirements not only increase cost but may also restrict ventilation equipment usage at same locations within the yard.



BRANCH ENTRY

Branches should enter at gradual expansions and at an angle of 30° or less (preferred) to 45° if necessary.



ELBOW RADIUS

Elbows should be 2 or 2 1/2 diameters centerline radius except where space does not permit.

Figure 3.6: Branch Entry and Elbow Radius Design for Ducting Layout

Same examples of static pressure loss for various types and sizes of are as follows (assume 9000 CFM ventilation requirement):

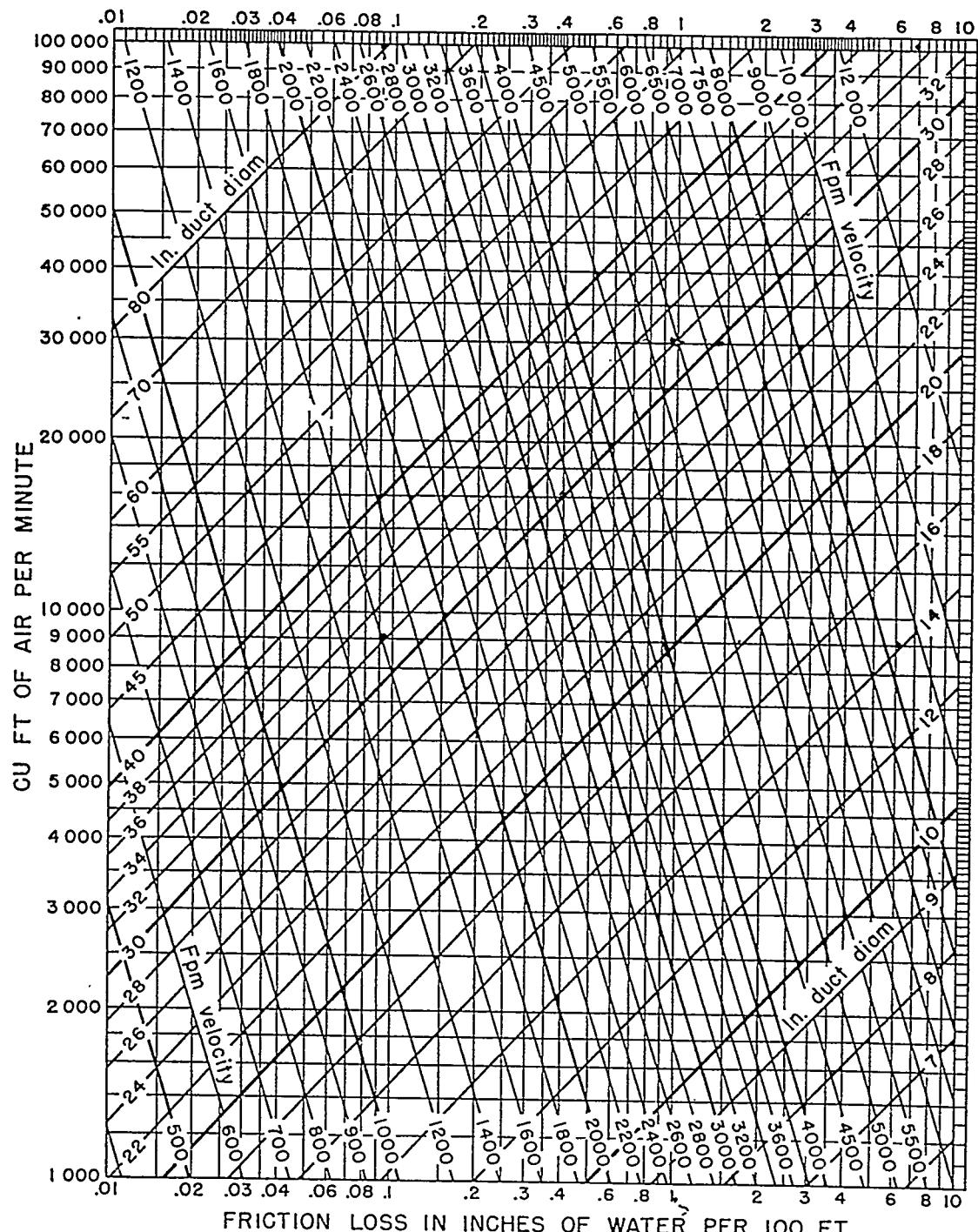
- 18" smooth ducting will generate 1.7" of static pressure drop 100' of duct, and will provide a velocity of 5,000 FPM. (See Table Iv)
- 18" flexible ducting has a static pressure drop of 2.8" per 100'. Adding one 90 degree bend along 103' will increase static pressure 'drop to 3.2". Two bards along -200' increases to 8.4" and three bends along 3(X) increases to 12.6". the **smaller** cross-sectional 'area inside the flexible ducting, due to **surface** irregularities, increases the velocity to 5,500 FPM as **compared** to the smooth ducting (see figure 3.6 for proper branch entry and elbow radius/ designs).
- **24" smooth ducting** has a static pressure drop of 6" per 100'. However, velocity at the velocity CFM is 3,200 FPM, which would be marginal to transport abrasive dust. The air volume would have to be increased in order to move grit dust through this duct size. (Accurate static pressure figures for various CFM and duct sizes can be obtained from manufacturer's specifications) .

Example: A ship tank is scheduled for abrasive blasting. The size and configuration of - tank is such flat 30,000 CFW of air and 300' of duct are required for proper ventilation. The available fan is a 30,000 CFM duct-axial. rated at 2" static pressure.

Step One: Look at Table iv. Select the line on the y axis which represents 30,000 CFM. As can be seen from the table, duct sizes from 20" to 80" in diameter diameter will carry the required air volume.

Step Two: Calculate the maximum allowable static pressure drop for each 100' of duct based on fan rating. This allows use of Table IV

TABLE IV - Frictional Loss Per 100 Feet of Ducting



id on Standard Air of 0.075 lb per cu ft density flowing through average, clean, round, galvanized metal ducts having approximately 40 joints per 100 ft.)

which is expressed in frictional loss in inches of water (static pressure) per 100' of duct length.

$$300' \div 100' = 3 \text{ lengths of } 100'$$

$$2.0" \text{ static pressure} + 3 \text{ length} = .7" \text{ per } 100' \text{ allowed}$$

Step Three: Again look at Table IV. Follow the x axis to the point which corresponds to a frictional loss of .7. Trace up this line to the intersection of the line which corresponds to 30,000 CFM. The diagonal line which intersects with x and y axis and represents 'in. duct diam.' reads 34. Therefore, the appropriate size duct appears to be 34".

Step Four: Verify that the duct size selected will maintain the proper velocity to keep abrasive dust suspended-3,500 FPM). The FPM velocity line is also a diagonal line. As can be seen, the velocity of the air ranges from 4500 to 5000 FPM which is in excess of the minimum velocity required to transport abrasive dust (3500 FPM).

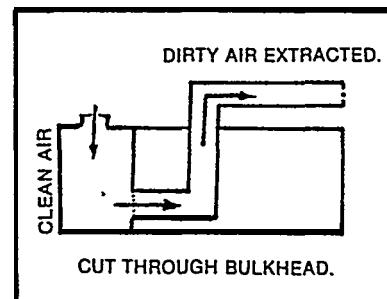
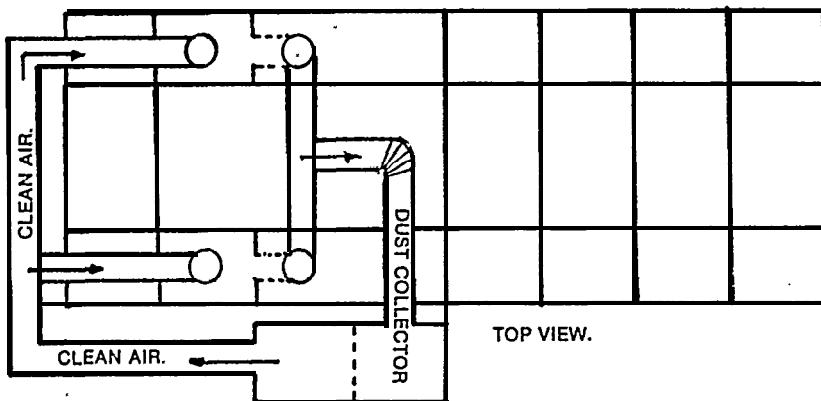
Solution: In this example the 34" ducting would be the correct choice.

In conclusion, ducting which is not carefully and properly sized will greatly reduce the efficiency of the total ventilation system, and will result in problems related to equipment, visibility and worker safety.

3.3.2.2 Layout

When blasting marine tanks, the operator is faced with many different types of applications and tank configurations around which the ducting layout must be designed. To allow for maximum portability and ease of set-up and breakdown, the yard should stock ducting components in a variety of sizes and quantities. However, the shipyard should have some standard systems which are designed for the most frequent types of jobs.

In many cases, ventilation air is not distributed uniformly through the tank. As a result, only parts of the tank are properly ventilated, while other areas remain contaminated. Clean air must be ducted into the tank in such a manner that the ductwork extends down no more than 6" below the tank top. Since the heavier airborne dust particles tend to settle to the bottom of the tank, the dirty air removal duct should be positioned in such a manner that the pick-up opening is near the tank bottom. This arrangement permits the dust particles to naturally fall toward the bottom of the tank and be exhausted much faster than if the pick-up point were positioned higher in the tank. The duct openings should be separated as much as possible. See Figure 3.7.



PROPERLY VENTILATING
TANK.

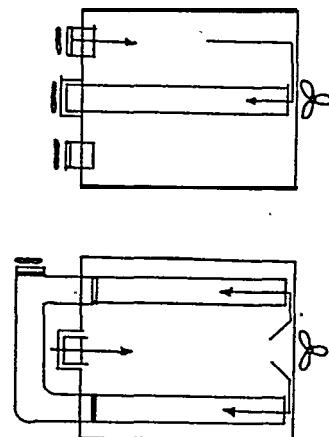
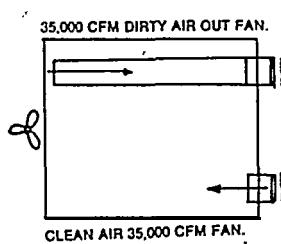


Figure 3.7: Ventilation Diagrams of Enclosed Spaces, Snail Tanks and Multiple Tanks

Some tank configurations and/or production requirements necessitate ventilation between tanks. This can be accomplished by cutting access holes through common bulkheads or through decks. These access holes are particularly advantageous when setting up a complete tanker job. The resulting cross-ventilation saves considerable time through standardization of duct sections. Blanks can be used to close off outlets or inlets when not in service. This practice also provides additional access entrances to each tank and avoids the constant problem of personnel and materials competing for too little space.

Metal ducting should be used for all straight runs. Flexible fabric-reinforced ducting, which is more expensive and is subject to high wear and tear, should be used for linking connections to machinery and to small, inaccessible tanks. Round duct is usually the best choice because it maintains a uniform air velocity and withstands higher static pressure. All duct work for tankblasting ventilation should be durable yet light for optimum portability.

After the system has been installed, periodic inspection of the ductwork should be made to insure air-tightness. In addition, every new **system** should include access for measuring devices to monitoring velocity, CFM and static pressure at various points along the ducting.

The Pitot tube is the standard air velocity meter. By multiplying the velocity reading in FPM by the cross-sectional area of the duct in square feet, the actual CEM at that point can be calculated. For example, at a point on a straight run of 18" ducting, the air velocity is measured to be 3,200 FPM. The 18" round duct has a cross-sectional area of 254.4 square inches, or 1.76 square feet. The CFM at that point would be $3,200 \times 1.76$ square feet or 5,632 CFM. See Table V for area and circumferences of circles. A manometer is used to measure static pressure.

If measurements of CFM, static pressure, and velocity reveal that ventilation objectives are not being met, modification or repair of the ductwork and/or the fan may be necessary. A common problem with fans used

TABLE V - Area and Circumference of Circles

Diam. in Inches	AREA		CIRCUMFERENCE		Diam. in Inches	AREA		CIRCUMFERENCE	
	Square Inches	Square Feet	Inches	Feet		Square Inches	Square Feet	Inches	Feet
1	.7854	.0054	3.1416	.2618	30	706.8	4.909	94.25	7.854
1 1/8	1.767	.0123	4.712	.3927	31	754.7	5.241	97.39	8.116
2	3.14	.0218	6.28	.5236	32	804.2	5.585	100.5	8.376
2 1/8	4.910	.0341	7.854	.6544	33	855.3	5.940	103.7	8.639
3	7.07	.0491	9.42	.7854	34	907.9	6.305	106.8	8.901
3 1/8	9.620	.0668	11.00	.9164	35	962.1	6.611	109.9	9.163
4	12.57	.0873	12.57	1.047	36	1017.8	7.069	113.1	9.425
4 1/8	15.90	.1105	14.14	1.178	37	1075.2	7.467	116.2	9.686
5	19.63	.1364	15.71	1.309	38	1134.1	7.876	119.4	9.948
5 1/8	23.76	.1650	17.28	1.439	39	1194.5	8.296	122.5	10.21
6	28.27	.1964	18.85	1.571	40	1256.6	8.727	125.7	10.47
6 1/8	33.18	.2305	20.42	1.702	41	1320.2	9.168	128.8	10.73
7	38.48	.2673	21.99	1.833	42	1385.4	9.621	131.9	10.99
7 1/8	44.18	.3068	23.56	1.964	43	1452.2	10.08	135.1	11.26
8	50.27	.3491	25.13	2.094	44	1520.5	10.56	138.2	11.52
8 1/8	56.75	.3940	26.70	2.225	45	1590.4	11.04	141.4	11.78
9	63.62	.4418	28.27	2.356	46	1661.9	11.54	144.5	12.04
9 1/8	70.88	.4923	29.85	2.487	47	1734.9	12.05	147.6	12.30
10	78.54	.5454	31.42	2.618	48	1809.5	12.57	150.8	12.57
11	95.03	.6600	34.56	2.880	49	1885.7	13.10	153.9	12.83
12	113.1	.7854	37.70	3.142	50	1963.5	13.64	157.1	13.09
13	132.7	.9218	40.84	3.403	51	2042	14.19	160.2	13.35
14	153.9	1.069	43.98	3.665	52	2124	14.75	163.4	13.61
15	176.7	1.227	47.12	3.927	53	2206	15.32	166.5	13.88
16	201.0	1.396	50.26	4.189	54	2290	15.90	169.6	14.14
17	226.9	1.576	53.41	4.451	56	2463	17.10	175.9	14.66
18	254.4	1.767	56.55	4.712	58	2642	18.35	182.2	15.18
19	283.5	1.969	59.69	4.974	60	2827	19.63	188.5	15.71
20	314.1	2.182	62.83	5.236	62	3019	20.97	194.8	16.33
21	346.3	2.405	65.97	5.498	64	3217	22.34	201.1	16.76
22	380.1	2.640	69.11	5.760	66	3421	23.76	207.3	17.28
23	415.4	2.885	72.26	6.021	68	3632	25.22	213.6	17.80
24	452.3	3.142	75.40	6.283	70	3848	26.73	219.9	18.33
25	490.8	3.409	78.54	6.545	72	4072	28.27	226.2	18.85
26	530.9	3.687	81.68	6.807	74	4301	29.87	232.5	19.37
27	572.5	3.976	84.82	7.069	76	4536	31.50	238.8	19.90
28	615.7	4.276	87.96	7.330	78	4778	33.18	245.0	20.42
29	660.5	4.587	91.11	7.592	80	5027	34.91	251.3	20.94

for blasting ventilation is worn impellers caused by abrasive dust. If the fan does not have sufficient capacity, ducting must be straightened or shortened. The problem may also be caused by improperly sized ducting, constrictions or air leaks.

Ducting that has been used for ventilation during painting should be inspected for paint build-up on the interior surfaces before it is used for blasting ventilation. Friction created by the abrasive dust combined with flammable paint solvent particles can create a fire hazard. In addition, excessive paint build-up will reduce the efficiency of the ventilation system.

In this section, basic procedures and guidelines have been given for general marine tank ventilation. Examples for the most part have been for ventilation of ambient, untreated air. The next section will identify the components of the dust collection system, which cleans the dust-laden air exhausted by ventilation.

SECTION 4

Dust Collection

4. Dust Collection

4.1 Introduction

The utilization of dust collection equipment to clean contaminated exhaust air resulting from manufacturing activities is an existing technology with widespread use throughout the world. The possible exception is shipyard adaptation of dust collection for blast-paint operations. If properly used by shipyards, dust collection will eliminate many of the problems associated with Contaminated air from abrasive blasting and Coating; operations, will insure compliance with EPA and OSHA regulations **and** will substantially reduce job-site housekeeping.

Current or pending federal legislation may seen force every shipyard **and** contractor to clean the contaminated air generated by abrasive blasting **and** painting. Clearly, management would be well-advised to begin assessing requirements and identifying dust collection equipment which will must efficiently meet existing and potential regulations.

4.2 Technical Discussion

There are three types of dust collection equipment which are adaptable to shipyard blast-paint operations.

- wet scrubber
- Dry Fabric
- DrY Cartridge

Wet scrubbers impinge the dust-laden air with moisture, wetting the dust and causing it to settle due to increasd weight. The resulting sludge is drained of moisture and discharged by conveyor from the machine in a semi-dry condition. One reccomended type of wet collector is of the venturi design. This design combines high constant efficiency and portability with low operating costs and low operating noise levels.

Dry fabric (baghouse) collectors use a series of fabric bags which filter dirty air drawn across or through the banks of filter elements (bags) . The retained dust is then removed at regular intervals by blowing compressed air through the fabric bags, by shaker or by vibrating systems . The dislodged dry dust then falls into hoppers for disposal. Reverse- jet continuous duty dry fabric dust collectors are recommended for shipyard applications because of the high humidity conditions. This design provides increased air flow and, therefore more complete cleaning of the filter media. However, this system has a higher initial cost and requires more maintenance.

Dry cartridge systems collect and discharge dust in the same manner as dry fabric or baghouse systems but have capacities of only 5-10,000 CFM. Because the cartridge is rigid in the collector, the filter media does not require removal for transport. Cartridges are replaced as necessary.

4.3 Equipment Selection

The most important selection criteria for dust collection equipment in the shipyard are as follows:

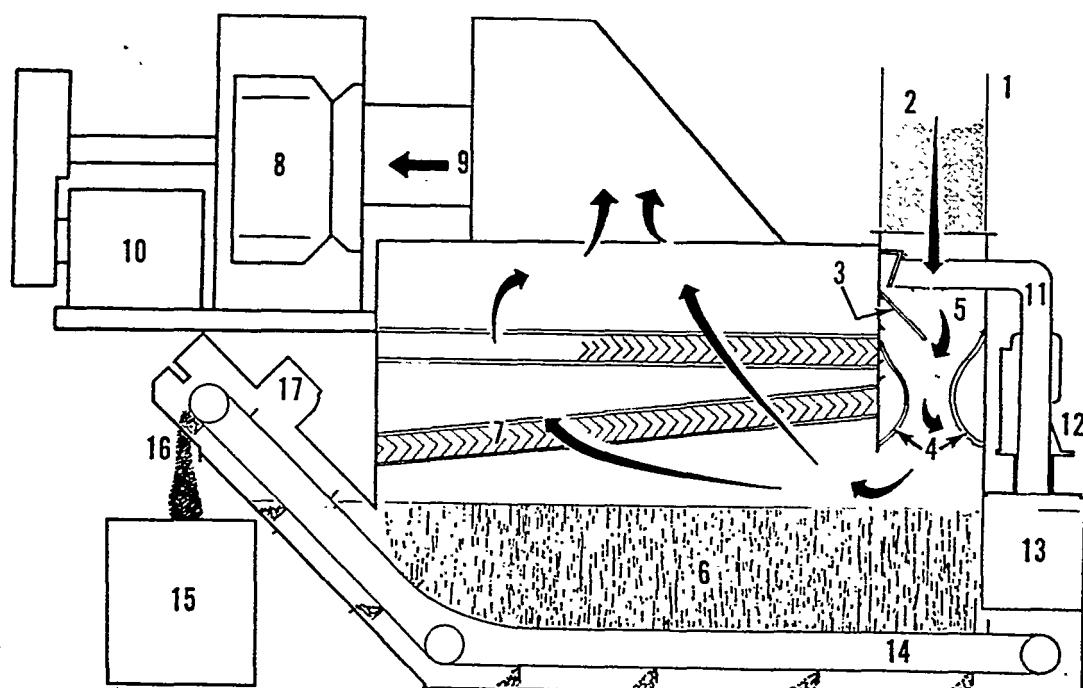
- o Portability
- o CFM and static pressure requirements
- o Type of particles handled
- o Efficiency and costs

4.3.1 Portability

Portability is a crucial consideration in selecting dust collection equipment, and includes factors such as machine size, transportability, set-up time and ease of placement.

If the shipyard frequently handles individual tank blasting jobs and/or multi-tank projects, a wet venturi system would be a good choice. This 25,000 CFM unit is compact (13.75' high X 8' wide X 18' long), with a dry weight of approximately 12,000 lbs. The wet scrubber can be transported

completely assembled. Because the fan is mounted on top of the machine, extra ducting is not required between the fan and scrubber. The unit can be disassembled or reassembled in about 8 man-hours. The removal of the fan and transition piece make it a legal load for transporting outside-the-yard. Due to a low center of gravity, the unit can be located ship without problems. See Figures 4.1 and 4.2. The primary limitation of the wet venturi system is that it cannot be used with dehumidification equipment. The moisture laden air increases the load on dehumidification equipment. When projects dictate dehumidified air, the dry fabric or cartridge collector is the recommended choice of equipment.



1 - CUSTOMER'S INLET DUCT	10 - FAN MOTOR
2 - INCOMING DIRTY AIR	11 - PUMP DISCHARGE
3 - WATER DISTRIBUTOR	12 - PUMP
4 - ADJUSTABLE RECTANGULAR VENTURI	13 - PUMP INLET
5 - WASH SECTION	14 - SLUDGE CONVEYOR
6 - SOLUTION TANK	15 - CUSTOMER'S SLUDGE CONTAINER
7 - MOISTURE ELIMINATORS	16 - SLUDGE CONVEYOR DISCHARGE
8 - FAN	17 - SLUDGE CONVEYOR DRIVE
9 - OUTGOING CLEAN AIR	

FIGURE 4.1 - Schematic of Venturi Wet Scrubber

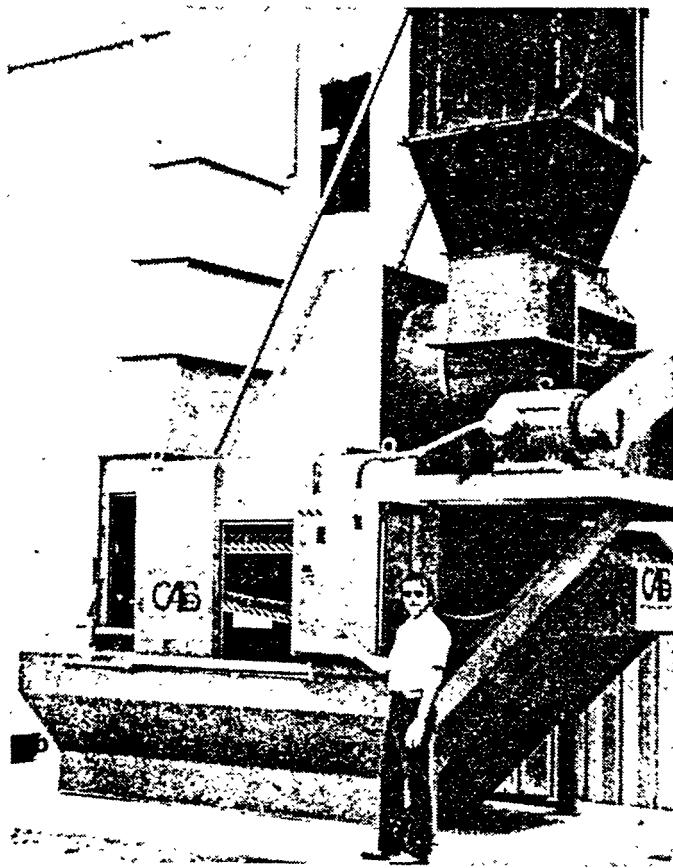


FIGURE 4.2: Venturi Wet Scrubber Dust Collection Unit - 25,000 CFM

The standard design of the dry fabric collector is less suitable for portability than the wet venturi or dry cartridge equipment, i.e., a 25,000 CFM unit is 27' high x 12' wide x 25' long and weighs about 13,000 pounds. It has a much higher center of gravity making it unstable when placed on the ship deck. If a dry unit is to be removed or transported, the bags usually should be removed to avoid tearing. Bag removal is a dirty and unpleasant task. In most designs, the fan and rotor are not mounted on the unit. These must be disconnected and transported separately for moving. Approximately 150 manhours are required to set-up or disassemble a 25,000-CFM unit. Frequent handling of this type of unit will result in increased maintenance and repair costs. See Figure 4.3.

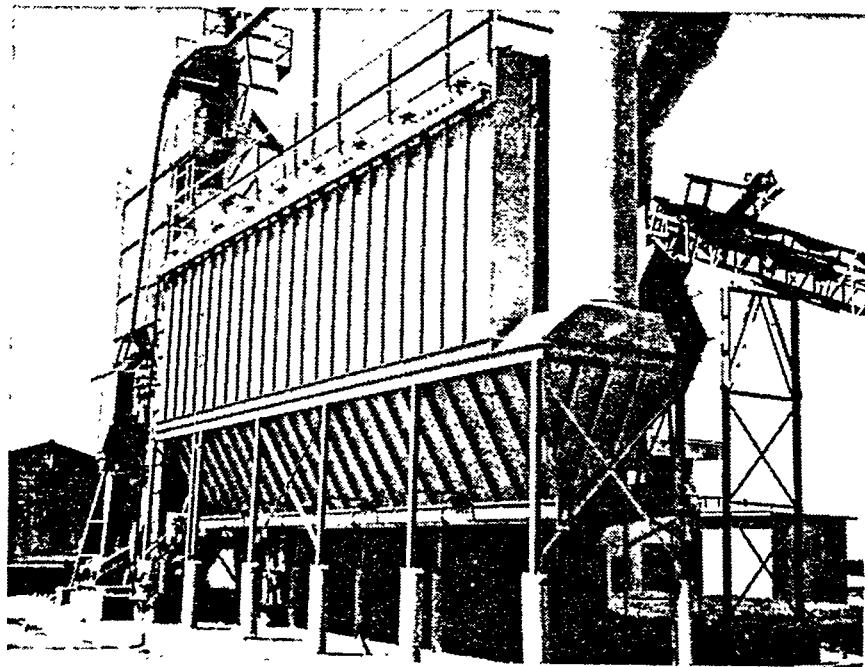


FIGURE 4.3: Reverse-jet Continuous Duty Dry Fabric Collector Unit
- 70,000 CFM

The dry fabric collector is most efficiently utilized in semi-permanent, pierside, barge-mounted, or railcar-mounted arrangements. This system is also appropriate for large capacity permanent installations.

For individual tank jobs requiring dehumidification, a combination of dry cartridge and dehumidification units (10,000 CFM each unit) represents a high-performance, totally portable system. (See Figure 4.4). The dry cartridge dust collector system is also ideal for trailer-mounting because of its compact design. A system of up to 40,000 CFM (consisting of four 10,000 CFM units) can be mounted complete with fan and motor on a single 40' trailer. Since the cartridge unit can be moved without disassembly, this system can be transported on roads as well as within the shipyard.

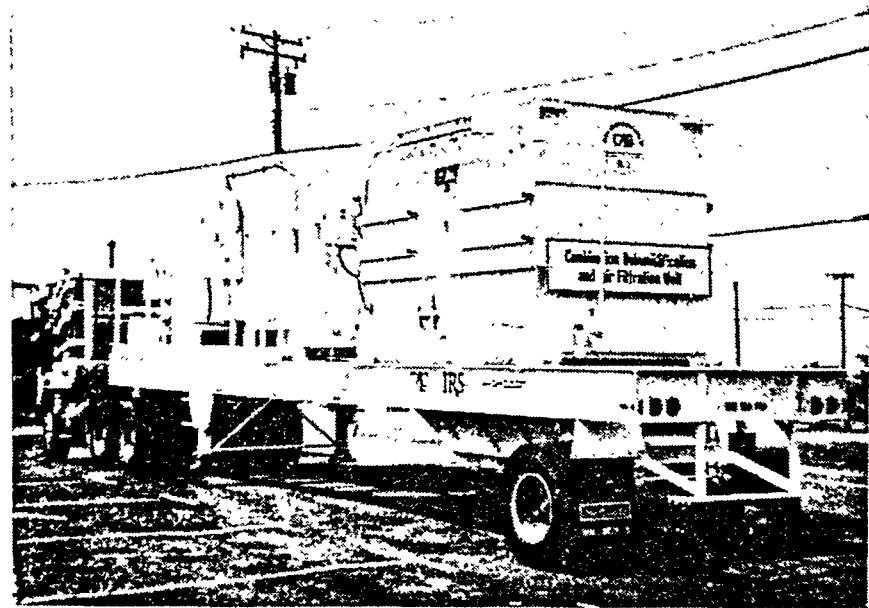


FIGURE 4.4: Mobile Dust Collection/Dehumidification System
- 10,000 CFM Each Unit

4.3.2 CFM and Static Pressure

Each type of dust collection system can be assembled with high static pressure fans to accommodate long runs of ducting. However, the Wet Venturi Scrubber is restricted to a 50,000 CFM volume capacity as the largest practical single unit. Because of their modular design, single units of the dry fabric system can be designed with a Capacity in excess of 100,000 CFM.

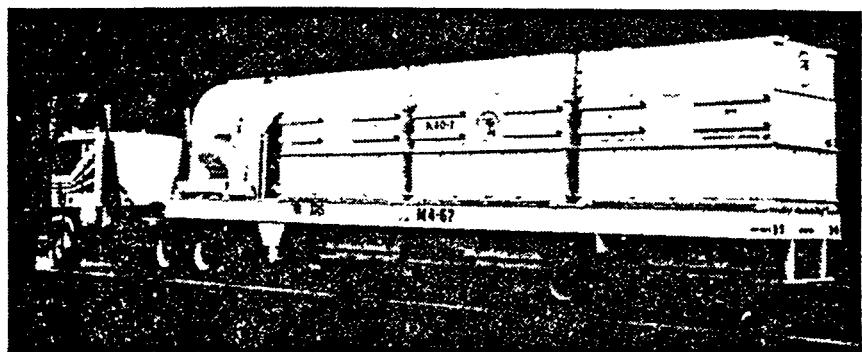


FIGURE 4.5: Mobile Dry Cartridge Dust Collection System- **40,000 (2'FM)**

4.3.3 Type of Particles Handled

Dust created by abrasive blasting institutes a moderate load of fine to medium sized particles. Both dry and wet systems are well-suited to handle these particles. However, the dry fabric collector cannot efficiently handle wet particles as they tend to clog the filter media. This problem limits the use of dry fabric collectors during matings applications because the overspray is wet. If air ventilated during painting is to be cleaned by a dry fabric collector, an expendable paint arrestor filter should be used to filter the air before it is exhausted to the collector. Wet paint will quickly clog and "blind" the bags.

The wet collector can handle both dry and wet particles. The slightly damp sludge resulting from the wet scrubber system is easier and cleaner to handle than the discharge from the dry system. The dry dust discharge can create a secondary air pollution problem during disposal.

4.3.4 Efficiency and Costs

In terms of efficiency, operating cost, and maintenance, the Wet scrubber offers several advantages. It runs at a constant efficiency, has heavy-duty construction with few moving parts, requires less maintenance and has lower replacement costs. The unit is also easily accessible for repairs and external inspection. The wet unit can be installed for all-weather, year-round operation. The efficiency of the wet scrubber is not affected by air moisture in humid areas, although the use of water may introduce corrosive conditions within the collector. When ordering scrubbers, a corrosion-resistant mating such as a coal tar epoxy should be specified for all internal metal surfaces. The scrubber requires both electrical and water service hook-ups, although water used by the unit is recirculated.

In comparison, the dry system will operate efficiently only when air conditions are dry enough to prevent condensation or moisture deposits on the fabric. Under humid conditions, dust will cake on the bags, resulting in low efficiency and possible damage to the filter media. All openings and

fittings on the suction side of the ductwork should be sealed against moisture. The unit has a large number of parts and assemblies with limited accessibility which results in increased maintenance costs. An additional hazard of the dry system is the possibility of a "baghouse" fire. The ferrous oxide contained in blast dust residue may under certain conditions spontaneously ignite. Use of the wet scrubber system for abrasive blast air-cleaning eliminates the possibility of collector fires.

4.3.5 Summary

In summary, actual equipment selection should be based on the performance requirements of the intended application. As a general selection guideline:

- For jobs requiring multiple units and volume requirements of **15,000 -35,000 CFM (especially** when frequent jobs of this range are widely distributed around the yard) the wet scrubber system should be used .
- For stationary applications requiring a single unit of over 35,000 CFM, the dry fabric collector is best.
- For small, portable, short-term applications and/or where multiple units are required for recirculation of dehumidified or heated air dry cartridge type collector of 5,000-10,000 CFM are best

If dust collection equipment is properly installed and utilized, the environment in and around the blasting operation will be as desirable a place to work as any other area within the shipyard.

SECTION 5

Dehumidification

5. DEHUMIDIFICATION

5.1 Introduction

Dehumidification (DH) is the process of removing moisture from ambient air. The removal of moisture from the ventilation air is an important process in preventing condensation ("sweat") on internal tank surfaces during blasting and painting. Condensation occurring on surfaces which have just been blast-cleaned may cause rust bloom formation within a short time. The resulting surface contamination promotes poor adhesion of the protective coating and premature failure due to underfilm Corrosion.

Blistering is another common type of paint failure usually causal by applying paint to a surface containing moisture. Blisters may also occur when the surface was originally dry during application but moisture entered the mating as it cured.

Paint curing is a function of temperature, time and humidity. Since curing requirements vary widely between water-born, epoxies, inorganic zincks, and other types of coatings, paint manufacturer's specifications should be consulted for recommended atmospheric conditions. The use of dehumidification equipment throughout the process of blasting, painting, and curing will prevent many coatings failures.

5.2 Technical Discussion

The purpose of this section is to provide simple, clear explanations of condensation principles and the calculation of dehumidification requirements. In addition, information will be presented on the comparison, selection and utilization of DH equipment. A series of easy-t-understand tables for calculating DH requirements have been developed to avoid the complex psychrometric interpretations that have hitherto been necessary.

5.2.1 Principles of Condensation

Condensation occurs when warm, moisture-laden air contacts a cooler surface. As the air next to the surface is cooled, the moisture carrying-capability is reduced, and some of the water vapor is deposited as droplets on the cooler surface. This occurs naturally in the early morning when air warmed by the sun contacts cooler blades of grass or car windshields.

The temperature at which the ambient air becomes saturated with water vapor is called the dewpoint temperature. Any reduction in the air temperature below the dewpoint (for example...when warm air contacts a cooler surface), causes moisture condensation. Reducing moisture in the air will lower the dewpoint temperature of that air. Dewpoint temperature is determined by the difference in the wet- and dry-bulb temperatures. This difference can be measured by a psychrometer. See Table VI, Quick Dewpoint Reference Table, for examples of dewpoint.

To determine dewpoint (air temperature at which moisture will condense on surfaces), follow wet bulb temperature across and dry bulb temperature down. (These temperatures can be measured by a battery-operated psychrometer, Figure 5.1). The intersection is the dewpoint temperature. Example; wet bulb 60°F, dry bulb 75°F = dewpoint temperature 50°F.

It is commonly believed that high air temperatures combined with high humidity create the greatest possibility of condensation. In shipyard operations, lower humidity combined with large day-to-night temperature swings and low sea water temperatures can present a greater potential condensation problem. During day-night temperature transition periods, surface temperatures will often be lower than dewpoint. Condensation in a ship tank can occur during these periods, or anytime that weather conditions change.

Once these general principles are understood, several points must be remembered in connection with the dehumidification of air in shipboard tanks .

TABLE VI. QUICK DEWPOINT REFERENCE TABLE

	DRY BULB TEMPERATURE °F														
	95	90	85	80	75	70	65	60	55	50	45	40	35	30	
90	89	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W	85	82	83	-	-	-	-	-	-	-	-	-	-	-	-
E	80	75	77	78	-	-	-	-	-	-	-	-	-	-	-
T	75	66	69	71	73	-	-	-	-	-	-	-	-	-	-
	70	57	60	63	65	68	-	-	-	-	-	-	-	-	-
B	65	45	49	53	56	60	62	-	-	-	-	-	-	-	-
U	60	26	35	40	46	50	54	57	-	-	-	-	-	-	-
L	55	9	22	30	37	42	47	51	-	-	-	-	-	-	-
B	50		0	17	27	34	41	46	-	-	-	-	-	-	-
					-4	15	26	33	40	-	-	-	-	-	-
T	40					-4	15	27	34	-	-	-	-	-	-
E	35						4	20	28	-	-	-	-	-	-
M	30							-12	11	24	-	-	-	-	-
P	25								-4	15					
	20														
F	15														
	10														

- Condensation will never occur if the dewpoint temperature of the air is kept lower than the surface temperature of the tank. Therefore, the general rule for condensation prevention is to maintain the air dewpoint temperature at least 5°F below the surface temperature.
- Heating the air in an enclosed tank does not remove moisture or change the dewpoint temperature. For example, air at 40°F with 70% relative humidity has a dewpoint temperature of 31°F, while 80°F air with 17% relative humidity has an identical dewpoint of 31°F.
- Dewpoint control can be easier to maintain when a ship is in the water than when in drydock. This is because the ship surface temperatures below the water line will remain relatively constant due to the heat sink of the surrounding water. When the ship is in drydock, the entire surface is exposed to air temperature shifts. Heat is also lost to the ambient air at night.

Psychrometric readings should be measured and recorded every four hours during the entire blasting and painting operation. This procedure will provide detailed records of job conditions for future use. The battery-operated Psychron Model 566, available from the Environmental Service Division of Bendix, provides wet- and dry-bulb temperature readings as well as a scale to determine dewpoint. A surface thermometer with built-in clamping magnets can be easily attached to metal surfaces anywhere on the ship for surface temperature readings. The Model 315F, available from Zorelco Measuring & Testing Instruments, 8520 Garfield, Blvd., Cleveland, Ohio, is suitable for this purpose. See Figures 5.1 and 5.2.

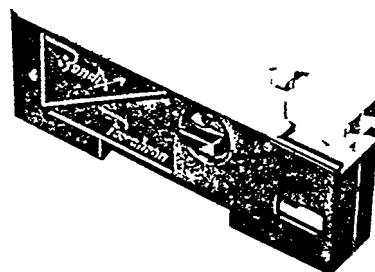


FIGURE 501: Battery Operated Psychron

Bendix

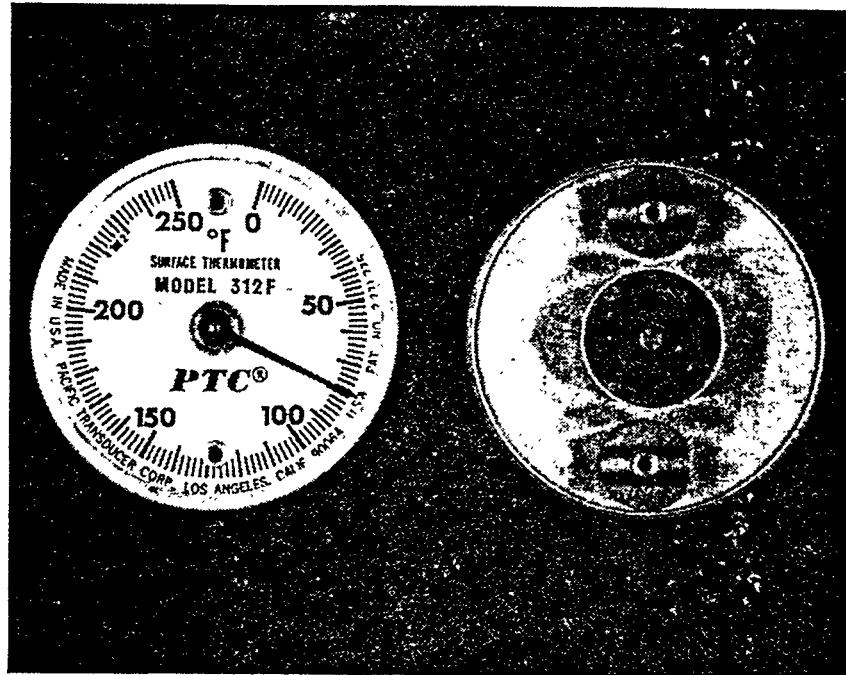


FIGURE 5.2: Magnetic Surface Thermometer

Zorelco

As an illustration of the practical application of dehumidification principles, the following example is offered. Readings were compiled over a 24 hour period and entered on a Psychrometric Report (See Figure 5.3). This proposed report is one way of recording required data. Note that relative humidity is not a required reading, and is only given as a comparison between air temperature and moisture-holding capacity.

(SAMPLE)

PSYCHROMETRIC REPORT

30B LOCATION NEW YORK HARBOR TANK WING TANK - SHIP WATERBORNE

DB-DRY BULB TEMPERATURE WB-WET BULB TEMPERATURE DP-DEW FOINT TEMPERATURE

DATE	TIME	FOREMAN	WEATHER*	OUTSIDE	INSIDE	TANK SURFACE TEMP	DIFFERENT SURFACE TEMP INSIDE DP
				DB WB DP	DB WB DP		
1/4/80	0800	WHITING	CLEAR	45/40/34	45/40/34	45 ABOVE W.L. 40 BELOW W.L.	+10F + 5F
	1200	WHITING	CLEAR	60/50/41	60/50/41	60 ABOVE W.L. 40 BELOW W.L.	+25F + 5 F
	1600	WHITING	CLOUD CHANGING	50/48/45	50/48/45	50 ABOVE W.L. 40 BELOW W.L.	+ SF - 5F
	2000	BIBBO	CLEAR	40/38/35	40/38/35	40 ABOVE W.L. 40 BELOW W.L.	+ 5F + 5F
	2400	CROTTY	CLEAR CHANGING	40/38/35	40/38/35	33 ABOVE W.L. 40 BELOW W.L.	- 2F + 5 F
	0400	GIESE	RAIN	50/48/45	50/448/45	33 ABOVE W.L. 40 BELOW W.L.	-12F - 5 F

* INDICATE: SUNNY, CLOUDY, RAIN, SNOW, FOG, CLEAR, (CHANGING).

FIGURE 5.3: SAMPLE PSYCHROMETRIC REPORT FORM

The following renditions are based on a 50,000 cubic feet wing tank ventilated with 17,000 CFM of air. It should be noted that a sealed tank with no ventilation would present very different characteristics, as the stagnant, idle air on the inside would not be subject to radical temperature swings.

8:00 A.M.

Water temperature	40°F
Ambient air temperature: dry-bulb	45°F
Ambient air temperature: wet-bulb	40°F
Dewpoint temperature (see Table VI)	34°F
Surface temperature: above water line	45°F
Surface temperature: below water line (relative humidity 80%)	40°F

Conditions at this time are condensation free, as surfaces both above and below Water line have temperatures above dewpoint. No DH required.

12:00 NOON

Water temperature	40°F
Ambient air temperature: dry-bulb	60°F
Ambient air temperature: wet-bulb	50°F
Dewpoint temperature (see Table VI)	41°F
Surface temperature: above water line,	60°F
Surface temperature: below water line	40°F

Conditions are the same as at 8:00 A. M., as only the ambient air temperature has increased. No DH requirement.

4:00 P.M.

Water temperature	40°F
Ambient air temperature: dry-bulb	5 0° _F
Ambient air temperature: ret-bulb	4 8° _F
Dewpoint temperature (see Table VI)	45°F
Surface temperature: above water line	50°F
Surface temperature: below water line (relative humidity 85%)	40°F

A storm enters the area, bringing additional moisture. This in turn raises the dewpoint 5°F above the existing temperatures of surfaces below the water line. Condensation will therefore occur on tank surfaces below the water line. The area above the water line, at 50°_F, is still 50°_F above the dewpoint temperature, so condensation will not occur on those surfaces. DH required below water line.

8:00 P.M.

Water temperature	40°F
Ambient air temperature: dry-bulb	- 40°F
Ambient air temperature: wet-bulb	38°F
Dewpoint temperature (See Table VI)	35°F
Surface temperature: above water line	40°F
Surface temperature: below water line	40°F

The storm has passed and ambient air is dryer. Surface temperatures, both above and below the water line, are again 5°F higher than the dewpoint. No DH required.

12:00 MIDNIGHT'

Water temperature	40°F
Ambient air temperature: dry-bulb	40°F
Ambient air temperature: wet-bulb	38°F
Dewpoint temperature (See Table VI)	35°F
Surface temperature: above water line	33%
Surface temperature: below water line	40°F

During the clear night, the surfaces of the Ship above the water line are radiation heat into space, so the surface temperature above water line drops to 33°F. This temperature will not drop any further because heat is also being transferred from the warmer surfaces below the Water line. In this case, condensation is occurring on surfaces above waterline, since the dewpoint is 35°F and the surface temperature above water is only 33°F. DH required above waterline.

4:00 A.M.

Water temperature	40%	--
Ambient air temperature: dry-bulb	50°F	
Ambient air temperature: wet-bulb	48°F	
Dewpoint temperature (see Table VI)	45°F	
Surface temperature: above water line	33°F	
Surface temperature: below water line	40°F	
(relative humidity 85%)		

Surfaces both above and below the water line have cooled during the night to temperatures below the dewpoint. Thus condensation will occur on all ship's surfaces exposed to ambient air. DH required.

During this 24-hour period, three different coditions were experienced.

- 4:00- P.M. the storm passed through and raised ambient air moisture levels. The dewpoint rose above the temperature of the surface below the ~~water~~ line caused condensation below the water line.
- 12:00 Midnight surfaces above the water line mold through heat radiation to a temperature lower than the dewpoint and condensation occurred.
- 4:00 A.M. condensation occurred on surfaces that had cooled during the night .

These examples demonstrate the types of conditions which are commonly experienced by shipyards. These conditions require dehumidification of the air to prevent condensation on tank surfaces. The following section outlines the methodology of determining dehumidification requirements.

5.2.2 Determining Dehumidification Requirements

Dehumidification requirements are determined by calculating the volume of conditioned air needed to control condensation inside a tank and then calculating the requisite number of DH units which will meet the defined objectives. These calculations can be easily accomplished by using data entered on the Psychrometric Report (Figure 5.3) in conjunction with Tables VI, VII, VIII. The instructions accompanying each table gives specific examples of required calculations.

Table VI gives the dewpoint temperature based on existing ambient dry and wet bulb temperature readings. Using the dewpoint and the existing tank surface temperatures, the amount of moisture in the ventilated air, expressed in pounds per hour per CFM, can be determined from Table VII. Determinations should be made for surfaces with above and below the water line. Table VIII contains the moisture removal capacity of a Cargocaire Model HC-9000 SEA Special 9000 CEM unit dehumidifier unit in pounds per hour. This model and size dehumidifier was chosen for the example because it is a standard readily available piece of equipment. A table similar to Table VIII can be compiled using performance curve data for any other

existing DH system. The total amount of ventilation required for visibility and safety (see Section 3: Ventilation) is then multiplied by the wet air factor (Table VII) to obtain the total amount of required moisture removal. Table VIII is then used to determine the number of DH units needed to meet the dehumidification requirement for the specified volume of air. This, in turn, is the required amount of conditioned air as a ratio to the amount of untreated ambient air required for ventilation.

Example: A ship tank is scheduled for abrasive blasting. The size and configuration of the tank is such that 30,000 CFM of ventilation is required. The dewpoint temperature of the ambient air is 50°F and the surface temperature of tank is 45°F. Dry Bulb Temperature of air is 75°F.

Step One: Determine the wet air factor from Table VII. At a dewpoint temperature of 50° and relative humidity of 45%, the Wet Air Factor is .011.

Step Two: Multiply ventilation requirement by Wet Air Factor
 $30,000 \text{ CFM} \times .011 \text{ lbs/hr/} \sim = 330 \text{ lbs/hr}$
This is the quantity of moisture to be removed.

Step Three: From Table VIII determine the moisture removal rate at a dewpoint temperature of 50°F and a dry bulb temperature of 75°F. In the example the water removal rate is 208 lbs/hr.

Step Four: Divide the quantity of moisture to be removed by the moisture removal rate of the dehumidifier. This will provide the number of units required.

$$330 \text{ lbs/hr} + 208 \text{ lb/hr/unit} = 1.59 \text{ units}$$

Solution: 1.59 or 2 units of 9,000 CFM capacity each are required. This means that approximately half of the 30,000 (2FM of ventilating air must be dehumidified.

TABLE VII

WET AIR FACTOR

TANK SURFACE TEMPERATURE

	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25
75		0	.014	.025	.035	.044	.051	.057	.062	.066	.069	—	—		
70			0	.011	.021	.030	.037	.042	.048	.051	.055	—	—		
D	65				0	.010	.019	.026	.032	.037	.040	.044	.048	—	
E	60					0	.009	.016	.022	.027	.031	.035	.038	.040	
W	55						0	.007	.013	.018	.022	.026	.029	.032	
P	50							0	.007	.011	.015	.019	.022	.024	
O	45								0	.005	.009	.013	.016	.019	
I	40									0	.004	.008	.011	.014	
N	35										0	.004	.007	.016	
T	30											0	.003	.006	
	25												0	.003	

To determine the amount of moisture in the air, follow dewpoint temperature across, surface temperature down (measure surface temperature of tank with a magnetic thermometer, Figure 5.2). The intersection is the wet air factor, in pounds per hour per CFM. Example: dewpoint temperature 50°F , surface temperature 45°F = .011 lbs.

TABLE VIII

	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25
D	75	284	320	356	392	428	—	—	—	—	—	—	—	—	—
	70	249	277	304	332	359	386	—	—	—	—	—	—	—	—
E	65	220	244	269	294	318	356	393	—	—	—	—	—	—	—
	60	179	202	226	249	272	310	347	384	—	—	—	—	—	—
W	55	162	182	202	223	243	260	278	295	312	—	—	—	—	—
P	50	139	156	174	191	208	221	234	247	260	266	—	—	—	—
O	45		152	160	179	196	214	217	220	223	226	—	—	—	—
I	40			150	164	179	180	181	183	184	185	—	—	—	—
N	35				127	136	145	148	150	152	153	154	156	—	—
T	30					116	119	122	121	121	121	121	121	121	—
	25						87	90	93	93	93	93	93	96	98
	20							69	70	71	72	73	74	75	
	15								52	53	54	55	56	57	58

This graph shows the moisture-removal rate of one (1) Cargocaire Model HC-9000 SEA Special 9000 CFM Dehumidification Unit under varying conditions. (Refer to manufacturer for performance data on other systems). Follow dewpoint temperature across, dry bulb temperature down. Intersection is moisture removal rate in lbs/hr. for model specified. Example: dewpoint temp. 50°F, dry bulb temp. 75°F = 208 lbs/hr.

5.3 Selection of Dehumidification Equipment

Three types of air treatment systems - be used to control dewpoint temperature.

- Air-conditioning
- Wet desiccant dehumidifiers
- Dry desiccant dehumidifiers.

Air conditioning cools air through the use of refrigeration coils to condense out moisture from the air. An air conditioning system may be adequate to control condensation in year-round warm climates; however, as the temperature approaches 45°F, moisture from the air will freeze on the coils making the system ineffective for dewpoint control. Furthermore, air conditioning units are not designed for rugged, dirty condition or portability. These units also require specialized maintenance. Therefore, air conditioning units have not proven to be reliable for typical marine coating applications.

Heaters are sometimes used to raise surface temperatures inside the tank above the dewpoint. While this method can theoretically control condensation, and can be effective for small tanks, it is extremely inefficient, uses excessive amounts of energy, and does not remove moisture from the air.

Until the late 70's, wet desiccant systems were the most frequently used in U. S. shipyards. This system operates by pumping a desiccant solution through a spray header tube in the contactor. When the air to be dried is drawn past the contactor, moisture in the air is absorbed by the desiccant. The moisture-laden desiccant is then cycled through an exhaust air stream which removes the collected moisture. The wet desiccant system requires piping and regular replacement of the desiccant solution, plus auxiliary support equipment. (See Tables IX and X). Wet desiccant humidifiers are not recommended for shipyards because of the high initial and maintenance costs, the requirement for a full time operator, and the large unit size and weight.

The dry system operates on the same basic principle as the wet unit, except that the desiccant is dry. The desiccant is usually attached to a rotating core within the unit. The dry desiccant unit is simpler in design and requires less auxiliary equipment, infrequent desiccant replacement, and lower initial and maintenance costs. In addition, it presents no corrosion problems and can be essentially self-cleaning. Because of its simplicity, portability, and ability to operate unattended (requires no adjustments), the design of this system is particularly well-suited for marine coating applications. For these reasons, this system has been selected by most shipyards and marine painting contractors in the U.S. (See Figure 5.4).

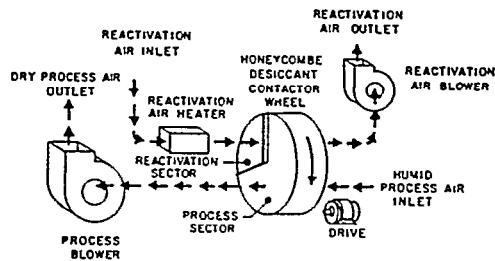


FIGURE 5.4: Schematic of Dry HoneyCombe Dehumidification Principle

DH units can be designed for CFM capacities from 50,000 to 100,000 CFM. For coating applications, where portability is an important factor, the most flexible size is the 9000 CFM unit (see Figure 5.5). When conditioning large volumes of air, the individual units are combined to produce the desired capacity. DH equipment can be located on deck, skid- or trailer-mounted pierside, or barge-mounted. If dirty air from the tank is to be cleaned, dehumidified, and recirculated to the blasting areas, the DH units must be located downstream from the dust collector.

TABLE IX
COMPARISON OF WET AND DRY DESICCANT HUMIDIFIERS

<u>Basis of Comparison</u>	<u>Wet System</u>	<u>Dry System (HoneyCombe)</u>
Auxiliary equipment required	Filters, reac. discharge duct and steam valves and traps, water valves	React. discharge duct steam valves and traps
Minimum delivery dewpoint	10°F	-60°F
Installation	Utilities Ducts Solution piping Regenerator (separate from conditioner)	Utilities Ducts
Cleanability	Replace solution (monthly analysis required)	Vacuum surfaces
Regeneration/ Process Air Separation	Separate units	Positive seals 0 leakage @ 12" 10-12 years life
Conditioner Housing Life Expectancy	12-15 years Corrosion	Unlimited, no corrosion (unit #1 still in operation after 15 years)
Dust Filtration	Scrubber effect (Contaminates and/or reacts with solution)	Self-cleaning. Particles up to 1000 microns will pass through wheel. 35% prefilter typical.
Humidity Control	Solution concentration Slow response	Bypass damper system Immediate response <u>+1%RH</u>
Suitable for outdoor installation	yes	yes
Shutdown precautions	Periodic running required	None required
Desiccant carry-over	Common (extremely corrosive) desiccant replacement required.	None
Desiccant crystallization	May occur - requires shutdown and cleaning	N/A
Energy modulation	Optional in response to moisture load	Optional in response to moisture load
Desiccant replacement	Check monthly, \$800 per 55 gallon drum	Permanent except for ambient sulphur. Typical field reimpregnation every 3/5 years. Cost \$200.

TABLE X
TYPICAL COMPARISON

The following table is a comparison of dehumidification equipment based on current catalogs. It is for a 6000 CFM dehumidifier operating at an inlet condition of 95°F, 120 grains per pound, using 100 psig saturated steam for reactivation energy.

<u>Supplier</u>	<u>Cargocaire (dry HoneyCombe)</u>	<u>Kathabar (wet)</u>
Model	HC-6000	1250 - 14C
Delivered air volume (scfm)	6000	6000
Utilities	460/3/60 electrics 100 psig steam	460/3/60 electrics 100 psig steam 85°F water
Weight (lbs.)	2150	9820
Floor space (sq. ft.)	60	97
Steam required (lb./hr.)	491	629
Electricity required (HP)	8 - 1/4	9

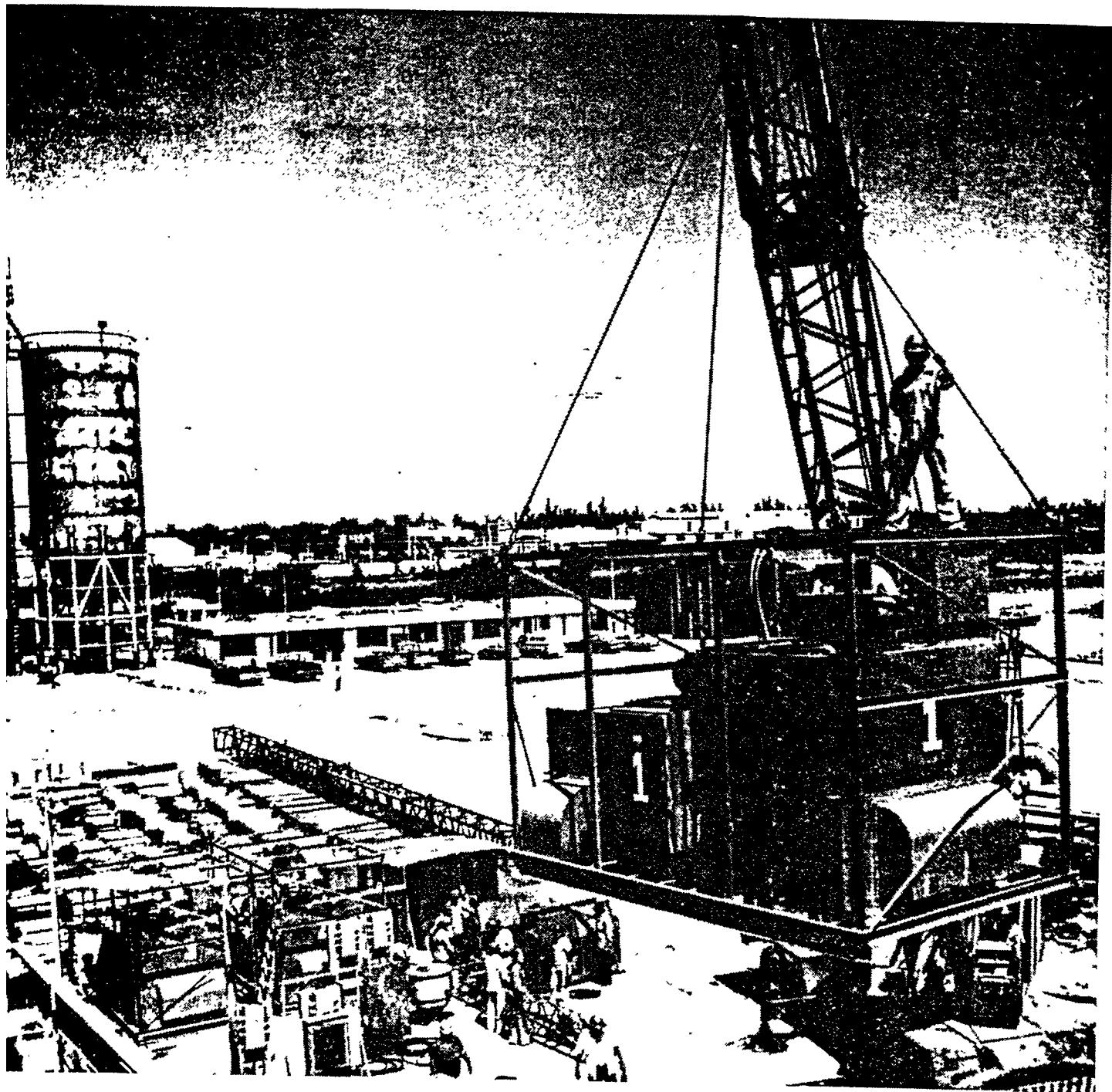


FIGURE 5.5: Model HC 9000 SEA Special Dry HoneyCombe Dehumidification Unit - 9000 CFM

SECTION 6

Abrasive Blasting

6. Abrasive Blasting

6.1 Introduction

Abrasive blasting is the process by which steel surfaces are cleaned of contamination through the use of abrasives striking the surface at relatively high velocity. This process requires a well-coordinated program of carefully selected equipment and materials, experienced operators, and organized services in order to guarantee success.

6.2 Abrasive Blasting Equipment

The selection and placement of the abrasive blasting equipment is critical to the success of any tank blasting project. This equipment requires the greatest amount of consumable materials (i. e., abrasives) used in the shipyard. A single abrasive blaster will use approximately 1,500 lbs. of abrasives per hour. An average cost for delivered mineral slag abrasive today is approximately \$40.00 per ton. Therefore, one blaster will consume .30 .00 worth of materials per hour. In addition, abrasive blasting requires a wide range of costly support services, including compressed air, crane service, dust collection, dehumidification, staging, and clean-up crews. Proper selection of equipment and materials can increase labor productivity and significantly reduce the amount of materials and services required.

In the past, small capacity blast machines were used. These units usually held between 600 and 1,000 lbs. of abrasives with a maximum resulting operating time of about 30 minutes. Shall abrasive storage hoppers of 3 to 5 ton capacity were placed overhead by crane or forklift. These timers require replacement at least once a day, and often more frequently. If a crane or forklift was not available to lift the hoppers, the machines ran out of abrasives, and the result was wasted manpower and lost production. On jobs which required large amounts of blasting, the use of these machines resulted in very low productivity and high abrasive

consumption (spillage). This size equipment should only be used for light-duty jobs requiring minimum blasting.

Larger capacity, bulk abrasive blasting machines with multiple outlets are now available. The main design features of these machines are:

- Large abrasive capacity which allows extended periods of uninterrupted operation.
- Bulk pneumatic refilling from delivery trailers. completely sealed system which provide weather protection for abrasives.
- Multiple-nozzle outlets and fast equipment set-up.
- Unattended machine operation.

These design features permit less dependence on crane service, less abrasive consumption, less labor, faster set-up and cleaner operation with little spillage.

The basic machine has a single chamber with operates 2 to 8 outlets. Both portable or stationary models are available with capacities from 6 to 40 tons. These machines are commonly manufactured in three sizes:

- 6-ton
- 22-ton
- 40-ton

Each machine is designed for a specific application. See Figures 6.1 and 6.2.

The 6 to 8 ton unit can be mounted on wheels or skid. A 22-ton machine is supported by legs and is basically portable. The 22-ton units are primarily used for larger spot-blasting jobs which require several operators working in a central area. This machine is particularly well-suited for spotblasting contaminated areas on new fabrications. Forty-ton units

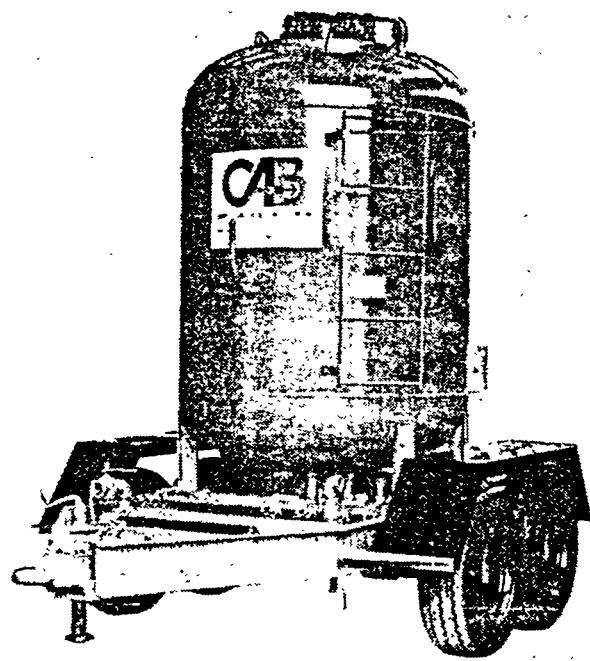


Figure 6.1: Portable Single-chamber Multiple Outlet Blast Machine
- 6 Ton Capacity

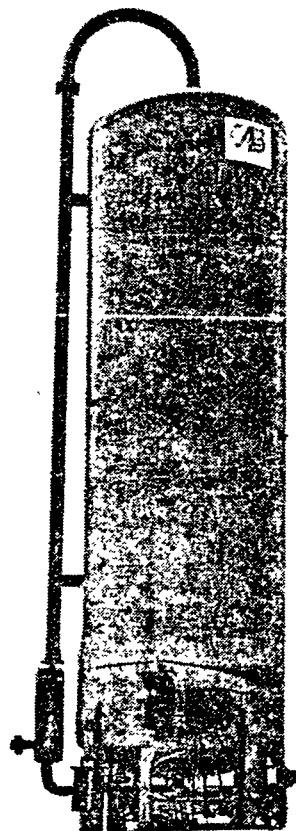


Figure 6.2: Single-chamber Multiple Outlet Blast Machine
- 40 Ton Capacity (Photos courtesy of CAB Inc.)

are usually used for stationary blasting projects in which the work pieces are transported to the blast area. These units provide sufficient storage capacity for several operators and are often used when high production rates are required. For large tank blasting jobs, or for external hull work, the 40-ton units can be mounted at the head of a drydock or aboard a ship.

In addition to single-chamber blasting machines, another type of system has been developed for large abrasive blasting requirements such as cleaning multiple tanks or huge repair jobs. This unit is a double-chamber system which fills automatically from overhead storage tippers. While maintaining the bottom chamber constant pressure, the top chamber can be depressurized and filled with abrasive. The abrasive will be automatically transferred to the lower chamber when the top chamber is closed. The blast operator is never stopped because of a lack of abrasives. This unit is especially recommended for the Shipyard which is pursuing internal tank blasting contracts. See Figures 6.3 and 6.4.

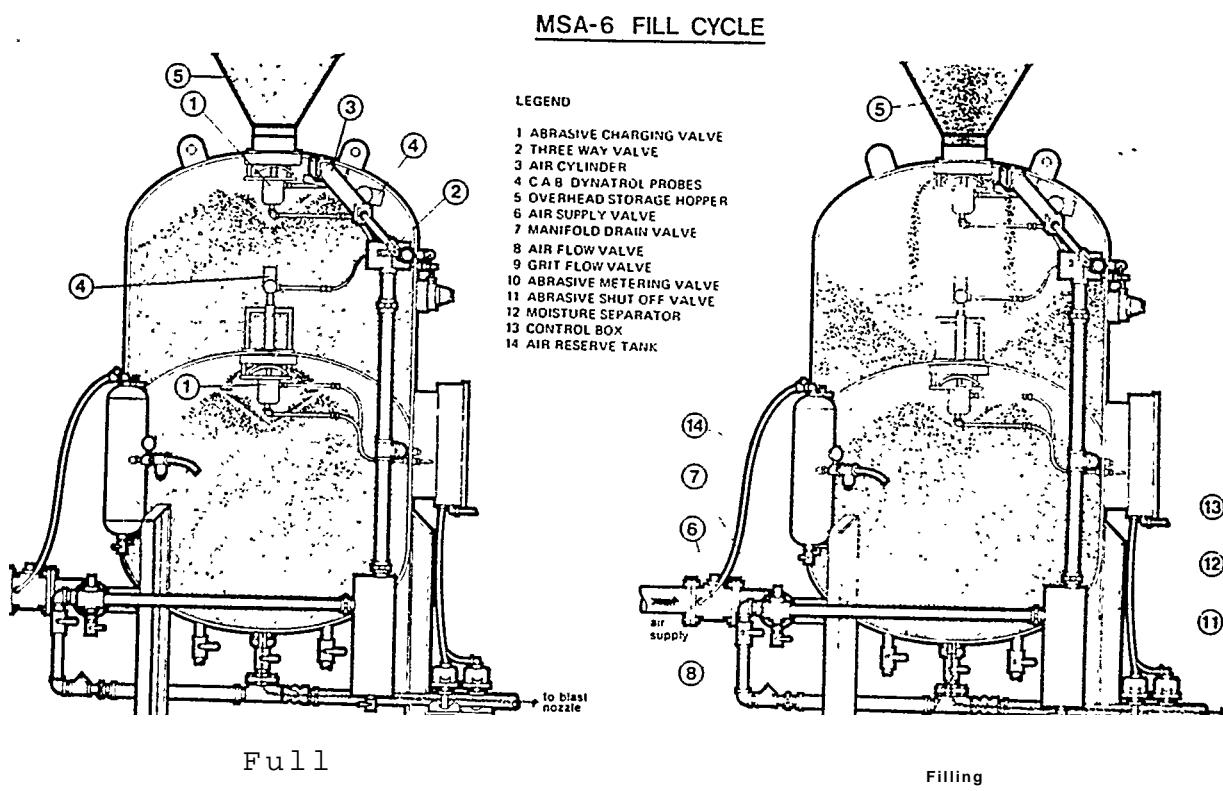


Figure 6.3: Schematic of Double-Chamber Automatic Filling Principle

In nest cases, the blast machine should be located as close to the work area as possible to avoid air pressure drop through the blast hose.

It is important to note that the properly sized blast hose and nozzle is essential to the operation.

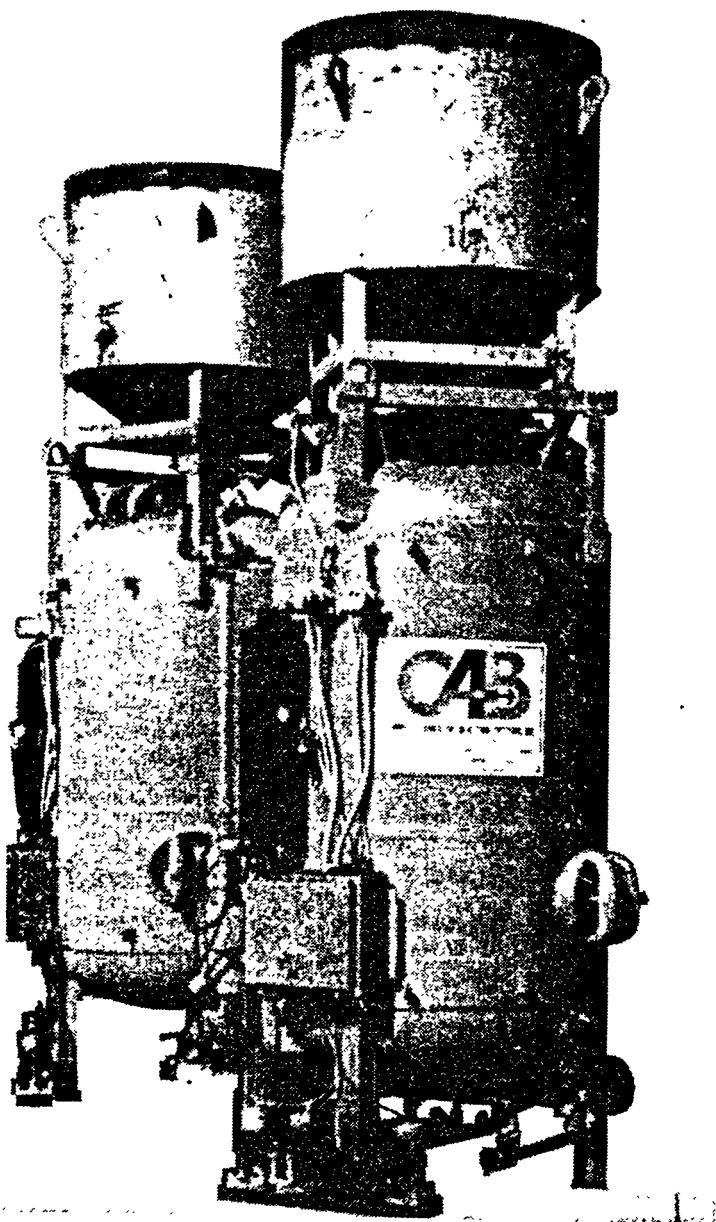


Figure 6.4: Double-Chamber Automatic Filling Multiple Outlet Blast Machine
(Photo courtesy of CAB Inc.,)

One method of locating the blast equipment close to the job site is to use a mobile, self-contained blast and recovery, trailer mounted system. Figure 6.5 is a picture of an existing mobile unit. This system is designed to recirculate steel abrasives. Refer also to Figure 6.6 which is a schematic which demonstrates one possible use for such a machine. In this system grit is cleaned (A) by means of a pneumatic separator. clean material falls into storage hopper (B) Dirty airborne dust is exhausted from can system. From the storage hopper, abrasive is directed into an automatic filling two-chamber blast machine (C) The abrasive is then transferred under pressure through the blast hose to the work area (H) Spent abrasive is manually vacuumed utilizing the vacuum (E) mounted on the trailer. Abrasive is deposited into a automatic dumping machine (1) which directly transfers collected abrasive back into the pneumatic separator (A).

For doing external work a special staging is required which will collect all the abrasive rebounding from the work surface. The blaster (B) stamps on a grated floor which permits the abrasive to fall through into a collection hopper. There, it is automatically collected by vacuum hose and returned to the trailer. Clean air is directed into the enclosure through a vent there dirty air is removed by an exhaust fan (F).

when selecting and utilizing blasting equipment, the following items should be noted:

- A single operator should be able to blast 100-250 sq. ft. per hour (depending on the condition of the steel surface) .
- Each 1/2" nozzle in operation will require approximately 1,500 pounds of abrasive (sand or slag) per hour.
- Each nozzle will require approximately 300 CFM at 110 pounds per square inch (psi) .

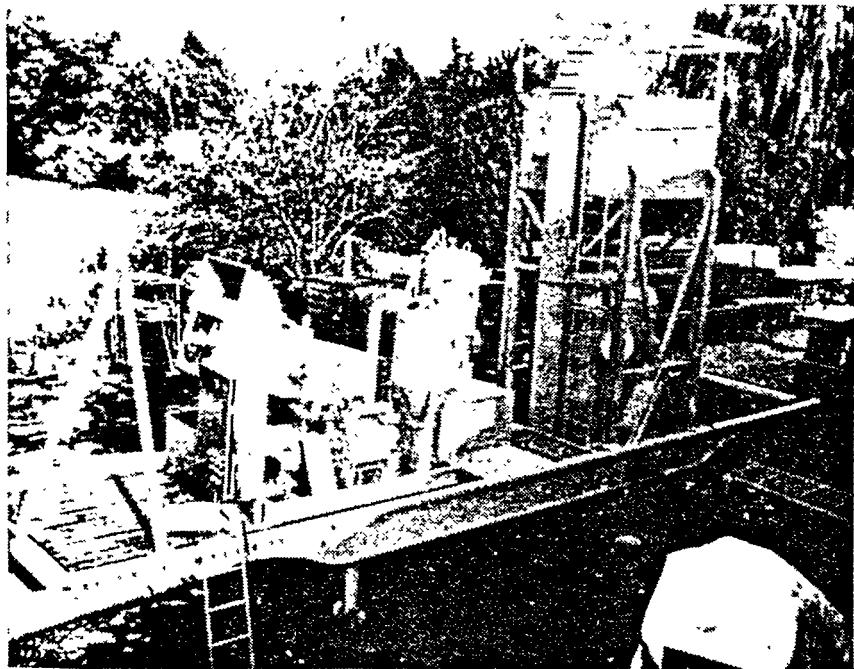


Figure 6.5: Mobile Steel Grit Blasting and Recovery System
(Photo courtesy of CAB Inc.)

Thus selection of new equipment must be based on:

- Existing compressed-air volume and pressure capabilities.
- Abrasive storage capacity
- Crane capacity
- Abrasive delivery schedule
- Number, frequency and location of blasting jobs.

6.3 Compressed-Air Drying Equipment

Compressed-air drying equipment is required to remove impurities from the compressed air system. Contaminants which normally enter the system include moisture and dirt from the ambient air, and oil from the compressor itself. As the air is compressed, these impurities combine to form an extremely dirty and corrosive mixture. The resultant contaminated air

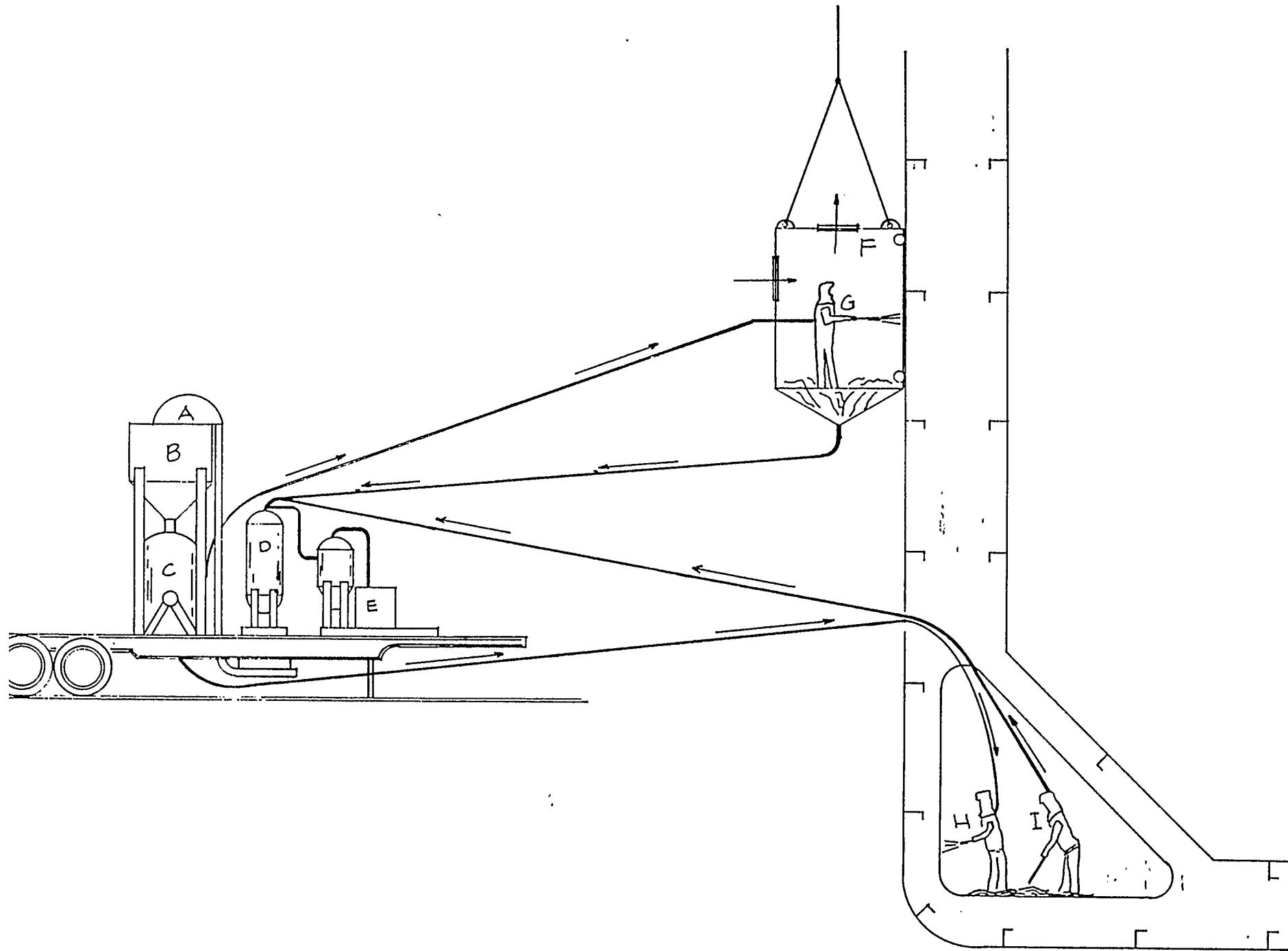


Figure 6.6: Schematic of Mobile Grit Blasting and Recovery System in Operation

drastically reduces the efficiency of the blast operation by clogging nozzles and depositing moisture and impurities on the tank surface. This condition will also contaminate abrasives and ruin steel grit abrasives.

There are three types of compressed air drying systems:

- Deliquescent
- Refrigerated
- Regenerate

For abrasive blasting operations, the deliquescent system provides the most trouble-free solution to cleaning and drying the air. In addition, it has the lowest initial cost and is least expensive to maintain. High-volume units are available which are constructed with lifting eyes to permit easy relocation. See Figure 6.7.



DELIQUESCENT COMPRESSED AIR DRYERS. Provide dependable dry, clean, compressed air with zero energy required to operate. Lower initial and operating cost than powered type dryers. Deliver a safe, compensating dew point about 20°F less than the entering air temperature, so no moisture can condense in your air system.

AIR-COOLED AFTERCOOLERS Economical Turbo-Cool Aftercoolers use atmospheric air (it's free!) to cool 350°F air from the compressor to within 5°, 10°, 15°, or 20°F to the ambient air, condense up to 70% of the moisture from the raw compressed air. Horizontal and vertical models for indoor or outdoor installation, capacities from 30 to 3500 SCFM.



FIGURE 6.7

Refrigerated units represent a complex system which requires qualified service personnel to assure dependable year-round operation. This unit is not well-suited for portable applications, or for use in areas where dirty, dusty air will contaminate the filter and condenser fins. For these reasons, refrigerated systems should only be installed in permanent indoor locations.

The regenerative system also requires qualified service personnel for maintenance. These units do not remove oil without the addition of pre- and after-filters, and are not designed for portable application without modifications for protection during handling.

Selection of appropriately sized equipment is based on the total equipment CFM requirement. A practical guide is to assume a service factor of 300 CEM delivered at 110 psi per blaster. If a central compressor is used to distribute air throughout the yard, the CEM delivered to any given point will not exceed the amount that is passed through the orifices in the blast nozzles. The CFM per nozzle can thus be used to estimate the total CFM of required compressed air.

Optimum utilization of the deliquescent dryer requires large volumes of air to be processed at high pressures. Therefore, it is important to measure air pressure available at the points where the dryers might be installed prior to ordering a system. As an example, a unit which is capable of processing 2,300 CEM at 125 psi may only process 1,550 CFM at 80 psi.

The location of the dryer depends on the compressed air distributing system, (i.e., portable or stationary). Since all air will be used outdoors, the dryer must also be located outdoors. The unit should be placed in the coolest area possible to avoid radical changes of temperature between the drying point and use point to prevent condensation in pipes downstream of the dryer.

In warm climates, when the temperature of the compressed air exceeds 100°F, an air- or water-cooled after-cooler is required to reduce the temperature of the compressed air. The chemical in the deliquescent dryer will be subject to deterioration in direct proportion to the rise in temperature over 100°F.

For portable applications, it is best to locate the dryer within 50' of the blast machine. This gives the air an opportunity to cool in the air lines before entering the dryer. In addition the dryer will catch any contaminants which might have entered into the system.

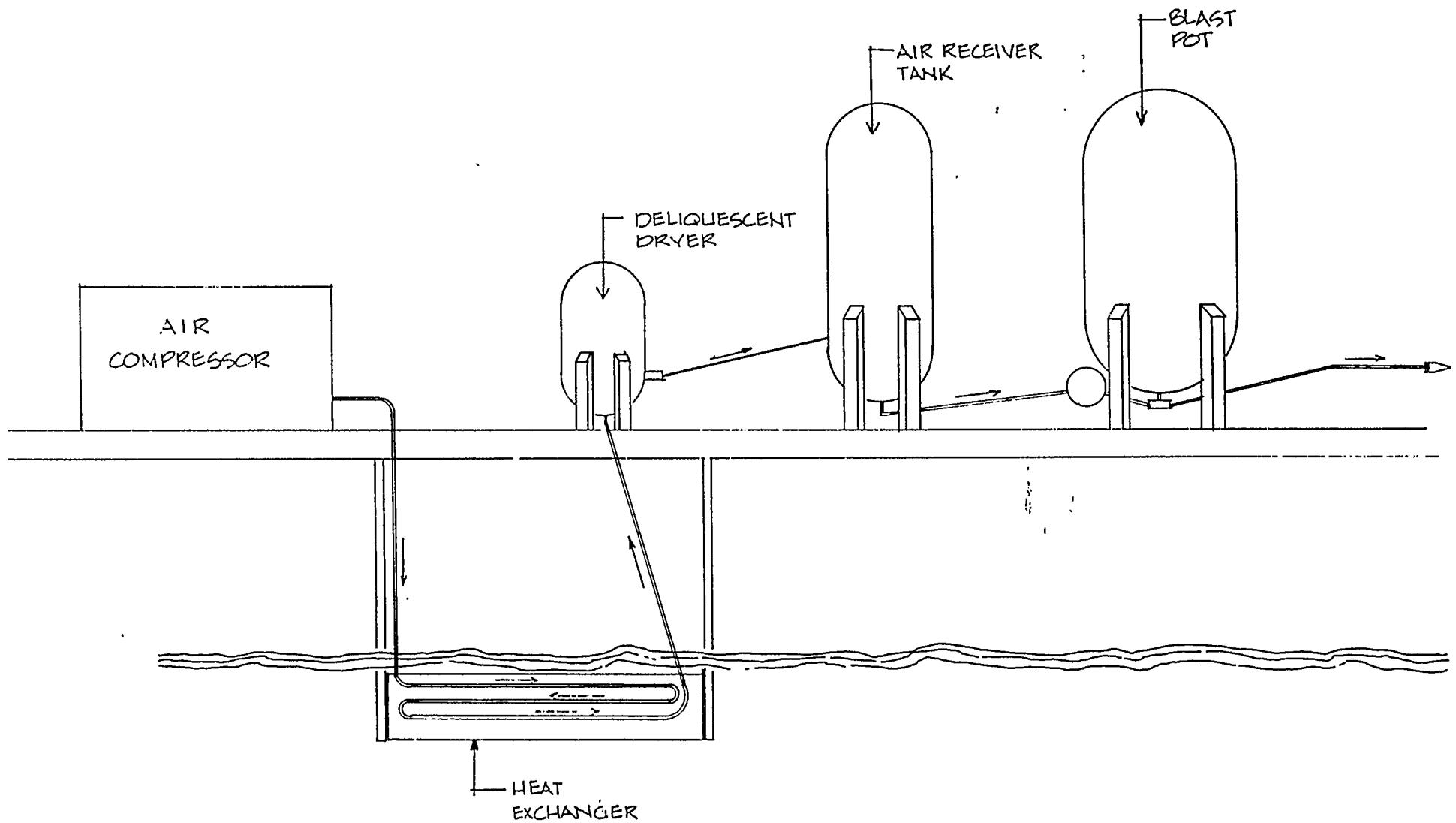


Figure 6.8: Model for Compressed-Air Drying System

Since abrasive blasting requires large volumes of air, often in surges, an air reserve tank is recommended. This tank should be at least equal in size to the CFM usage and be installed downstream of the deliquescent unit. Normally, a receiver is placed ahead of the dryer to allow additional cooling exposure before entering the dryer. If an after-cooler is used on a portable basis, it should be placed in a location that will insure maximum ambient air flow around the unit. Often times a surplus heat exchanger may be used as an after-cooler. Air is circulated through the tubes while the unit is immersed in the water (Figure 6.8).

Compressed air is passed through a submerged heat exchanger to cool it and to remove the moisture from the air stream. The air is then passed into a chemical deliquescent dryer for final removal of contaminants. Compressed air drying equipment offers the final assurance for proper surface protection and coatings application. It also eliminates plugging or clogging of abrasives in the blast machine caused by moisture.

6.4 Abrasive Delivery and Storage

In the past, abrasives were delivered to the shipyard and distributed to the blast machine hoppers in a variety of ways from hundred pound bags to railcars.

Today, the most efficient method for distributing abrasives to blasting locations within the shipyard is by pneumatic delivery trailers. These units are operated at low pressure, and transfer the abrasives pneumatically through a discharge hose to the blast machine or storage hopper. See Figure 6.9.

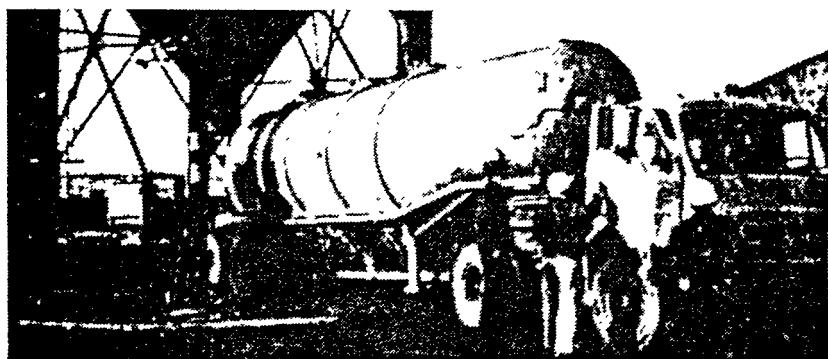


FIGURE 6.9: Pneumatic Delivery Truck

The main advantage of this trailer unit is mobility and the direct transfer of the abrasives for use in blasting. If a local supply of abrasives is available, and if the blasting equipment is accessible to the trailer, materials can be picked up and transferred directly to blast machines.

If the supply source is distant, installation of a large-capacity bulk storage hopper should be considered. The storage hopper can be loaded directly from a railcar or truck. Depending on the quantity of materials used and the time needed for replacement materials to arrive, this storage hopper should have a capacity of from 500 to 1000 tons. See Figure 6.10.

Large sealed portable hoppers should also be made available for installation in areas where frequent blasting takes place, or where the pneumatic trailer cannot reach blast units. These units should be sized as large as possible without exceeding the lifting capacity of available cranes. The hoppers can be filled by the pneumatic trailer and then lifted by crane and positioned over the blast units. By decreasing the number of lifts required, these large hoppers can reduce the number of times cranes are required.

Distributing and storing abrasives in completely enclosed pneumatic delivery trailers and storage tippers also reduces the possibilities of spillage and moisture contaminations. If delivery and storage in large bulk is feasible, purchase of a yard-owned pneumatic trailer will reduce the overall cost of the operation. Materials can be bought in bulk and the labor required for handling and distribution will be reduced.

6.5 Abrasive Recovery Equipment

6.5.1 Selection Criteria

After a ship tank has been blast cleaned, spent abrasives, abrasive dust, and paint chips must be removed in order to ready the tank for painting. Usually this is accomplished by vacuum machines which suck the particles and other debris out of the tank through a flexible hose.

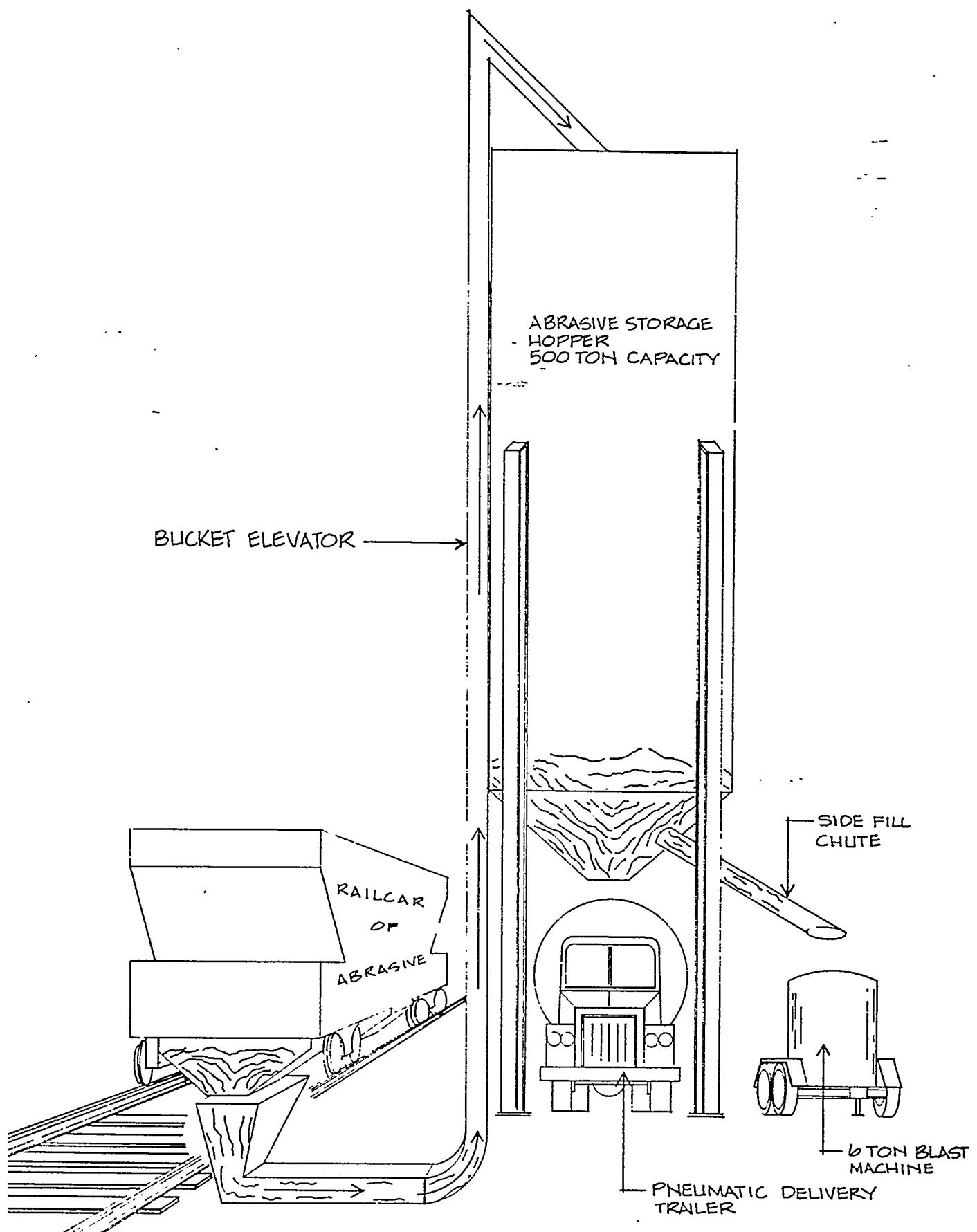


Figure 6.10: Delivery and In-plant Distribution System for Abrasives

There are three different types of vacuum recovery machines available:

- Portable unit with single-chamber collection tank
- Portable unit with automated discharge tank
- Mobile truck unit with single-chamber collection tank

In selection a vacuum recovery system for shipboard tank blast-cleaning, the following criteria Should be considered:

- Equipment operation with reduced labor
- Support services requirements
- Equipment size in relation to available space in the work area
- Hose size needed to operate at maximum efficiency
- Initial and maintenance rests

6.5.1.1 Portable Unit with Single-Chamber Collection Tank

The portable single-chamber vacuum recovery tank is designed to operate unattended and can be located close to the worksite. This unit is equipped with an easy to handle, flexible 4" hose. The unit does not use fabric dust filtration media, and the vacuum producer can be separated from the collection tank. These equipment characteristics allow for flexibility in setting up the vacuum system. If the unit is to be positioned on deck, a crane is usually required for placement.

Suction is created by a high-performance liquid ring-type vacuum purpose. The average abrasive removal rate of the unit is ten tons of abrasive debris per hour. In addition, this type vaccum pump can handle large amounts of dust particles which carry over from the secondary dust cyclone tank (larger particles settle out) . The unit is powered by a 50 to 70HP motor and requires water and electrical service hook-up. Both equipment maintenance and initial crest are low (\$25,000). See Figure 6.11.

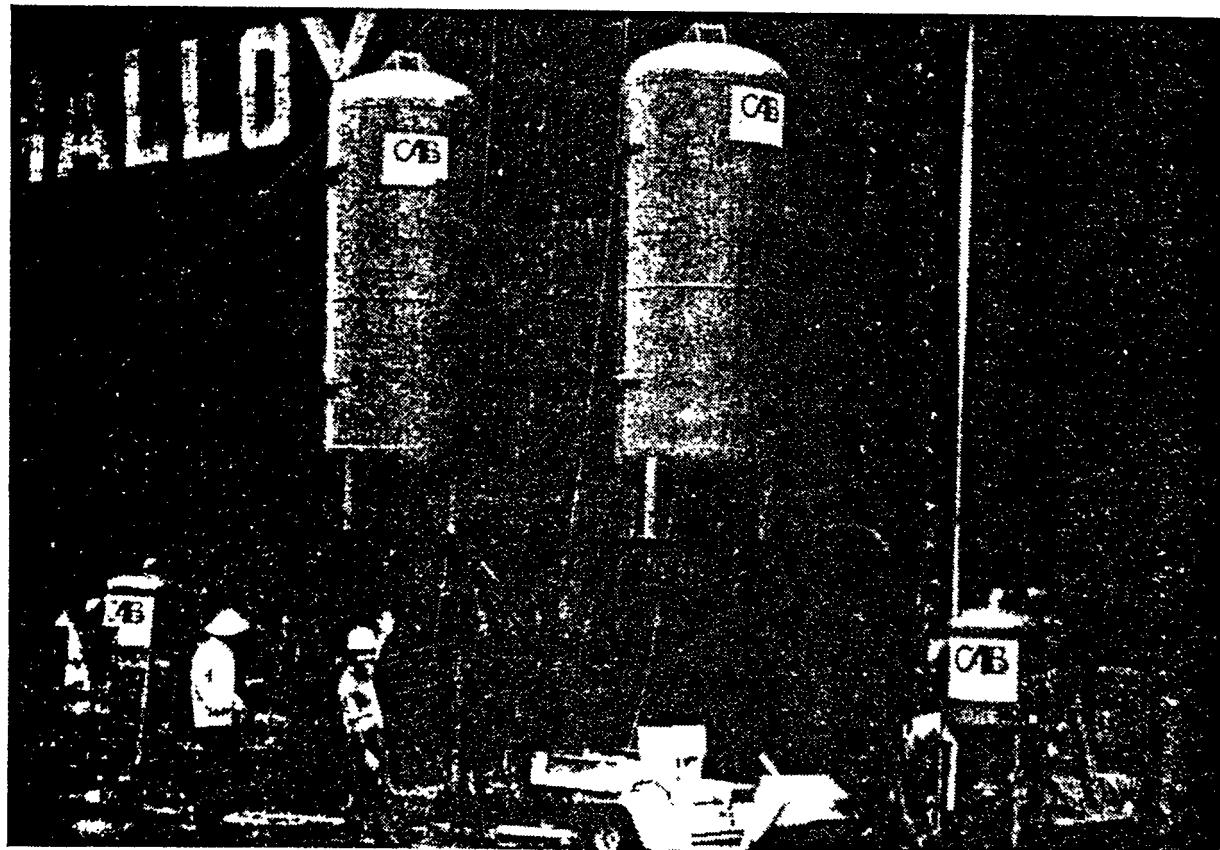


Figure 6.11: Two Portable Vacuum Units with single-chamber Collection Tanks hunted on Stands

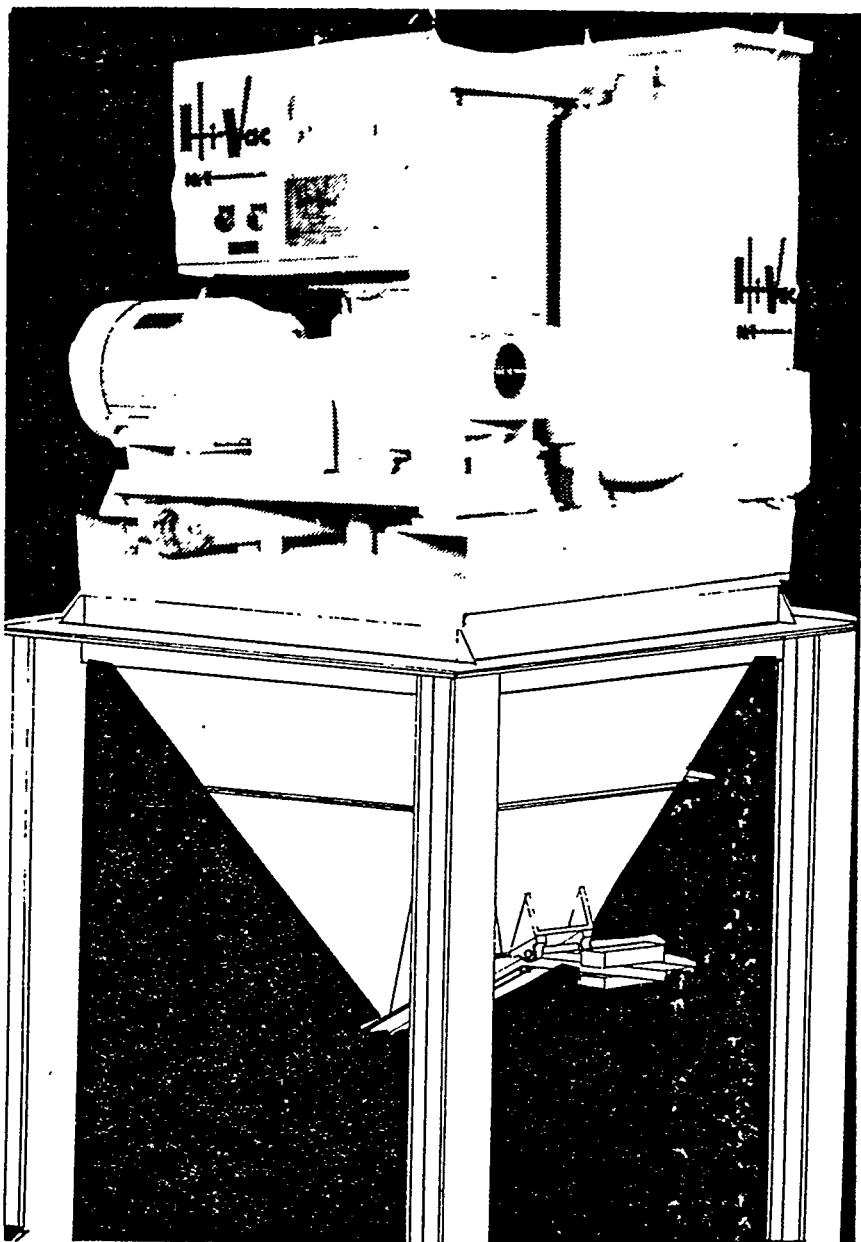


Figure 6.12: Portable Vacuum Units with Automatic Discharge Tank

Portable single-chamber units can be hooked up to a pneumatic discharge device if the material is to be disposed directly from the area without using a tank. The collection tank of the portable single-chamber unit can be placed on an elevated platform so that a dump-truck can pick up the abrasives for disposal or recovery.

If abrasive recycling is desired, the collection tank insures that the recovered abrasives are protected for reuse.

6.5.1.2- Mobile Unit with SingleChamber Collection Tank

This unit is permanently truck-mounted for mobility. The unit has an average production rate of ten tons per hour. Performance is increased by moving the unit closer to the job site which is sometimes difficult in shipyard operations. Some units are capable of removing water and other fluids. This system is designed to operate with a 6" to 8" hose and is equipped with a positive displacement vacuum pump.

Being mobile, this unit requires an attendant. The power take-off unit which is driven by the truck engine requires increased maintenance, especially when used on a continuous basis. The truck system can only be operated for short periods at a time before being shut down and driven away for disposal. The initial cost of the mobile unit is high (about \$125,000) See Figure 6.13.

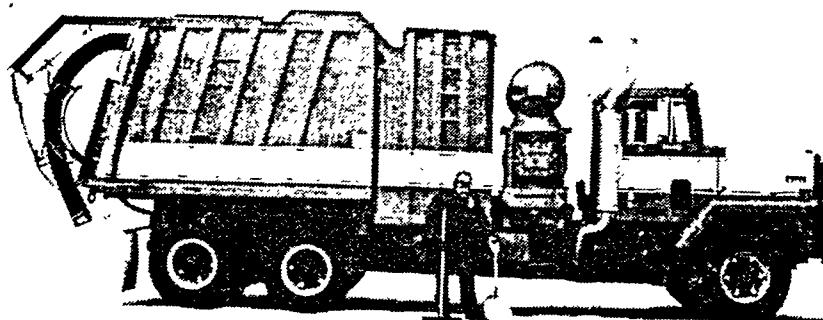


Figure 6.13: **Mobile Vacuum Recovery Truck with Single+Chamber Collection Tank**

Although the mobile unit is suited for some shipyard applications, maintenance requirements and short-cycle performance make it impractical for most internal tank-cleaning jobs.

6.5.1.3 Portable Unit with Double Chamber, Automatic Discharge Tank

This unit can be moved to an area where needed for abrasive recovery. No attendant is necessary and each component can be separated. It is designed to operate with a 4" to 6" hose and has an average obtainable production rate of ten tons per hour. Like the portable single-chamber units, the initial cost is relatively-low (35,000 - \$40,000); however, the dust collection filter must be periodically replaced.

Suction is produced by a positive displacement, rotary vacuum pump. These pumps are subject to damage should any dust carry-over from the air filter system. The pump can be troublesome if not properly maintained. The large number of moving parts are an additional disadvantage resulting in increased maintenance costs. See Figure 6.12.

The portable unit with double-chamber automatic discharge tank is not suited for must tank vacuuming. Debris removed along with the abrasive cannot pass through the discharge valves and may lodge between the valve and seat, resulting in a vacuum leak.

SECTION 7

Model High Production Abrasive Blasting and Coating Pier

7. Model High Production Abrasive Blasting and Coating Pier

The high production abrasive blasting and coating pier should be established in an area which can be totally dedicated to painting and painting related activities. The pier area should be large enough to accommodate the largest ship requiring painting. Ships can remain in the water. Figure 7.1 shows a panoramic (photographic) view of such a layout. In this photograph some of the important aspects of the operation can be seen. These activities are listed below. The photograph is numerically keyed to the activity number.

1. Bulk abrasive is delivered by railcar or pneumatic truck and is transferred into one of two 1,000 ton capacity storage hoppers (also see figure 7.2). Bucket elevators are used to unload the railcars. These operations require minimum labor and the abrasive stays dry regardless of weather conditions.
2. Mounted below each storage hopper is a double-chamber, automatic-filling, multiple outlet blast machine (also see figure 7.2). These machines are automatically filled without the necessity of an attendant. Eight blasters can operate from each blast machine.
3. Two inch I.D. abrasive blasting pipes are routed through a trough below grade level to the ship. The pipe size permits long runs with minimum pressure drop. Grating is placed over the troughs to permit crossing.
4. The ship is moored to the pier. (Just off photograph.)
5. Portable vacuum units with single chamber collection tanks are mounted on stands to permit discharge into a disposal truck (also see figure 5.9). These units can be lifted and placed adjacent to the point of use to reduce vacuum hose length. In this photograph the units are stationed alongside the ship.

6. Dehumidification units are skid mounted for placement aboard ship (also see figure 5.5).
7. The facility should also contain a high pressure water main for wash-down (not shown).
8. A duct storage cradle should be used to move large amounts of duct without damage (not shown)
9. Dehumidification duct should be prefabricated in sections to accommodate long runs with minimum set-up time.
10. Dust collection duct is also prefabricated.
11. A 5000 gallon #2 diesel fuel storage tank is located adjacent to compressor station.
12. The air compressor station must have sufficient capacity to provide compressed air to 16 blasters plus additional gear. A 6000 CELL compressor station is shown. This station is equipped with a water cooled aftercooler to insure that the temperature of the compressed air entering the dryer is less than 1000F. This compressor is diesel powered to facilitate portable application.
13. Pier management and quality control are located in an office on site.
14. A portable crane is necessary to provide lifting services.
15. A shelter can be used to provide protection for inclement weather and the sun.
16. A staging platform cradle can be used to enable the crane to lift larger amounts of scaffolding (not shown).

Figure 7.3 is a photograph which shows a ship docked at the abrasive blasting and coating pier. The portable dehumidification units are located

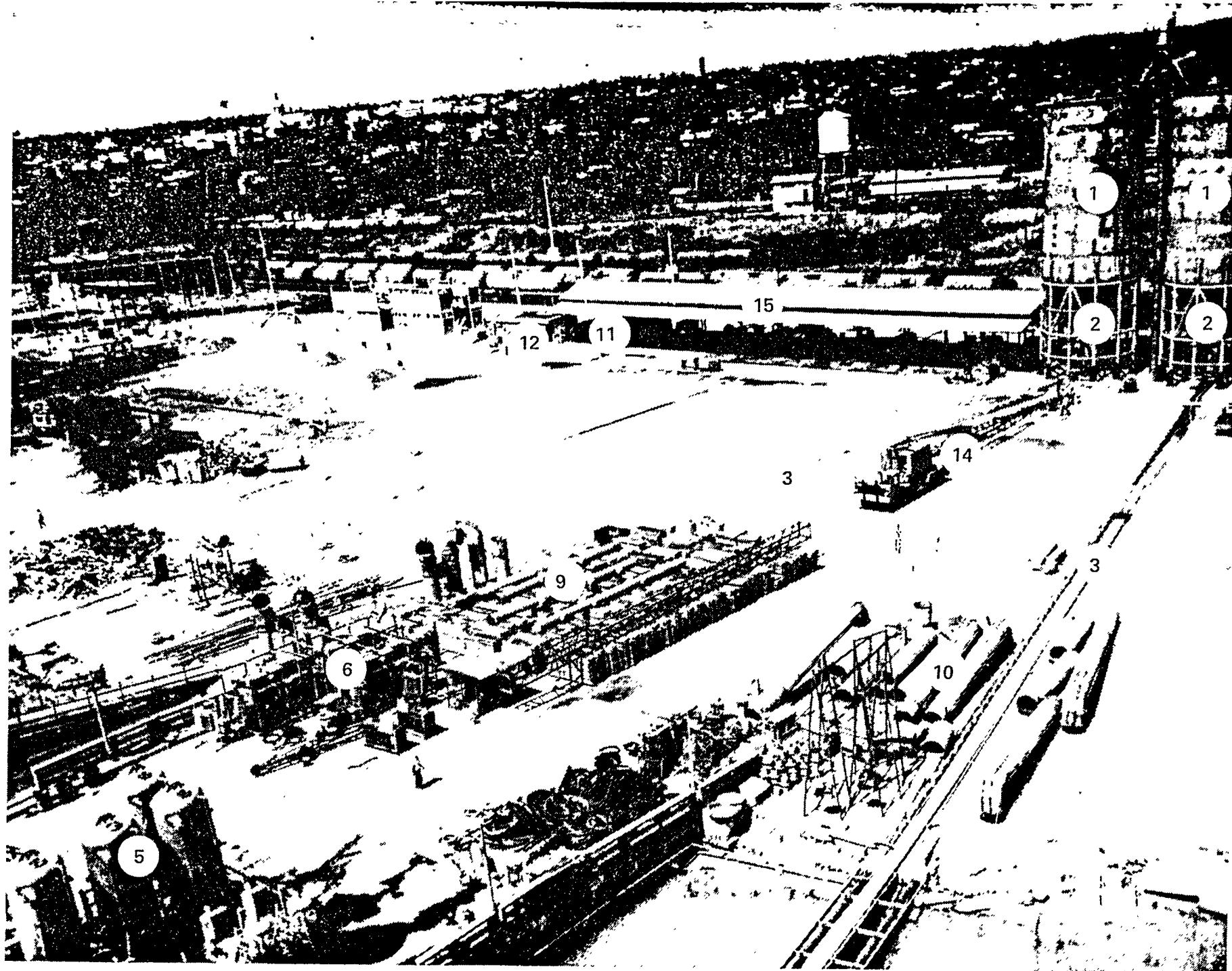


Figure 7.1: Photograph of Sample High Production Abrasive Blasting and Coatings Pier

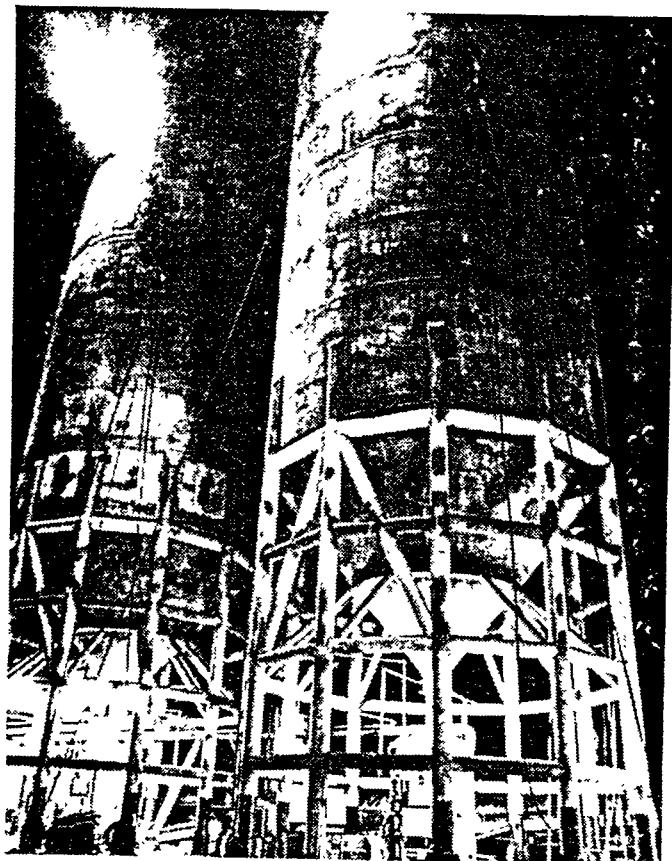


Figure 7.2: Close-up of 1000 ton capacity Abrasive Storage Hoppers

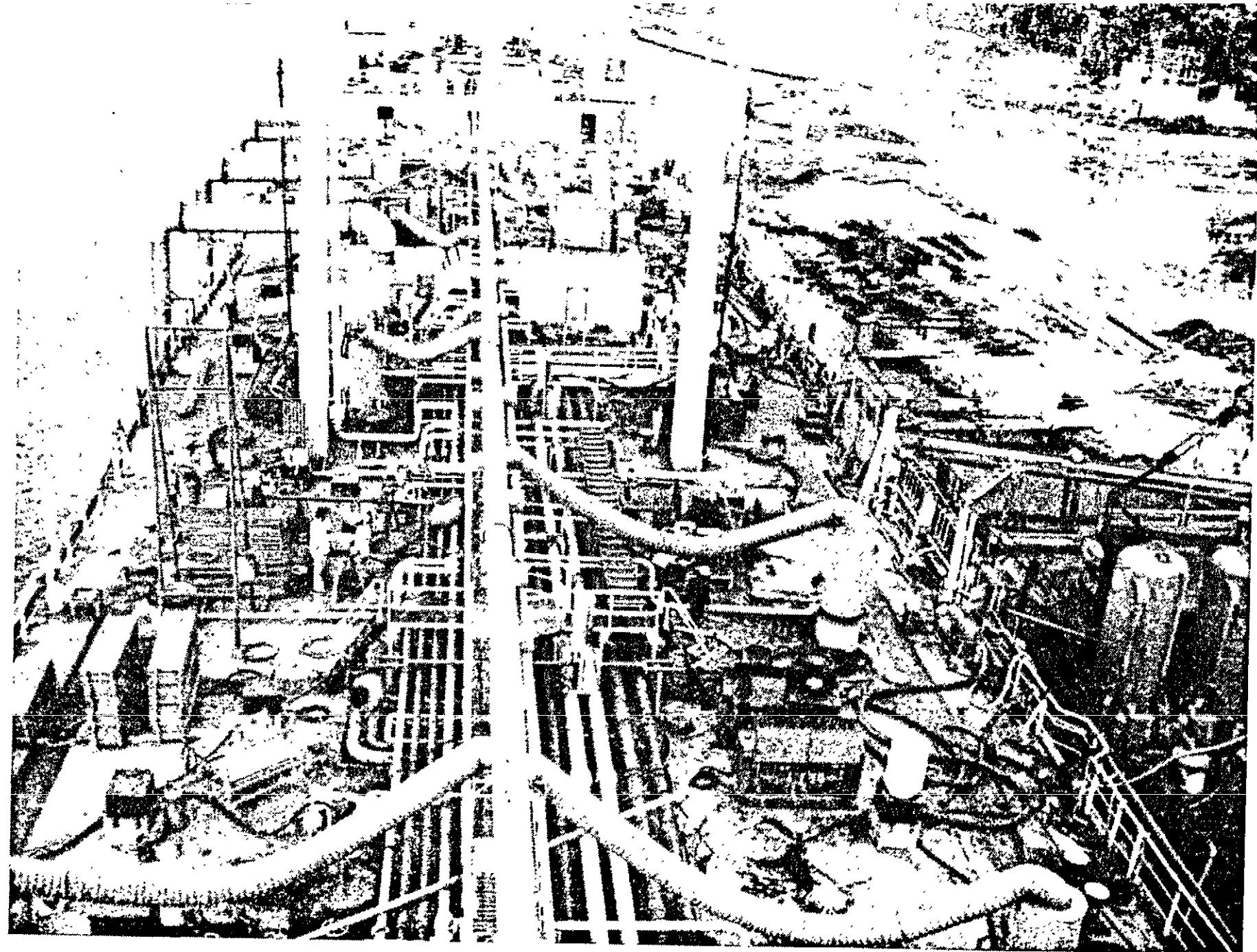


Figure 7.3: Ship Docked at High Production Abrasive Blasting and Coatings Pier

midship with prefabricated ducts extending forward and aft. Flexible ducts are connected between the prefabricated ducts and the cargo access ports (hatches). The dust collecting duct can be seen midship on the port (water) side. There are three difference ducts. Each duct has two 90° turns which positions the discharge end over the side of the ship and into barge mounted dust collection equipment. Four each vacuum recovery units are mounted on the dock on the starboard (land side) side of the ship.

Figure 7.4 contains a schematic of a unit coating container. These containers are designed such that all painting equipment and materials necessary for a specific area are kitted prior to starting the job. The container is then positioned as close to the actual operation as possible. The unit matings container provides a clean, sheltered work center.

Figure 7.5 is a cross-sectional drawing of a large ship cargo tank. The cargo tank covers have been removed for personnel and equipment access. In some cases equipment is placed directly over the openings.

Dirty air (detail A) is extracted from the tank internal by duct work from the intake side of a fan. In most all cases efficiency of the ventilating process is greatly improved by running the duct work the shortest possible distance. Even when a penetration through the side shell is required, the procedure is generally less expensive than running ductwork through the ships interior. A dust collector should be used to clean the dust-laden air before being exhausted. Clean air can be routed into the work space from a penetration in bulkhead of an adjacent tank or be directed into the tank parallel to the dirty air exhaust duct. If a dust collector can be conveniently located pierside, substantial saving in set-up time will be achieved with a mobile unit.

On projects or climates which require dehumidification (detail B) either a mobile or portable unit may be used. If the volume of air required is too large for a single III unit the the DH air may be recovered and recirculated by cleaning the dirty exhausted air by a dust-collector. This process of recirculation enables the dew point to be continually controlled in the work space utilizing a minimum of DH.

For an area requiring a large air volume (detail C), fresh ambient or treated air may be introduced into the tank through the car~ hatch cover. Dirty air should be extracted near the bottom of the tank and conveyed by duct through fans and collected on the ship's deck. Sometimes large access holes are required in the deck. In these cases, special openings should be made for duct access as well as for personnel lifting devices.

Figure 7.6 is a close-up drawing of a ship tank area. Limited access into the area can be improved with penetrations thru bulkheads, side shell, and/or decks. Fresh ambient or conditioned air should be introduced at the highest access point. The exhaust intake should be at the lowest point within the tank and on the opposite side from the fresh air inlet. Blind spots of stagnant" air inside tank can be prevented with proper placement of duct . Consideration should always be given to recycle treated air as dotted line indicates.

When performing blasting and painting operations in closed tanks, several safety points must be remembered. All abrasive blast equipment, operators, nozzles and the object that is being blast cleaned must be grounded. Procedures must be established to control entry into tanks and enclosed areas until such time as the area is declared "gas free" by a trained and certified competamt person. For tanks that have been in service, this should be accomplished prior to initial entry, after Work breaks and prior to the start of a new shift. All lighting must be explosion proof. At least one person should be positioned outside the tank, adjacent to the access in case of emergency.

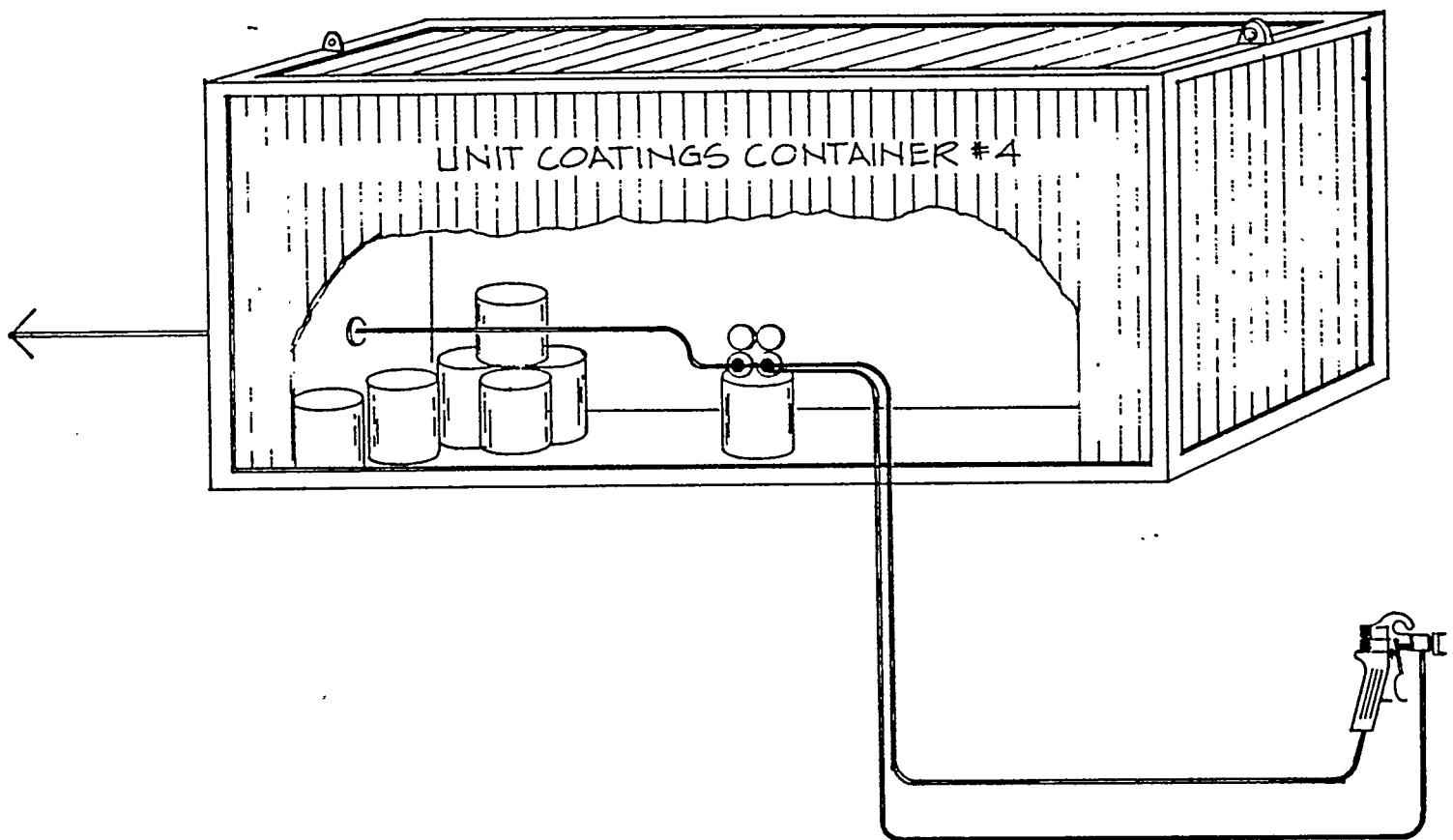


Figure 7.4: Drawing of Unit Coatings Container

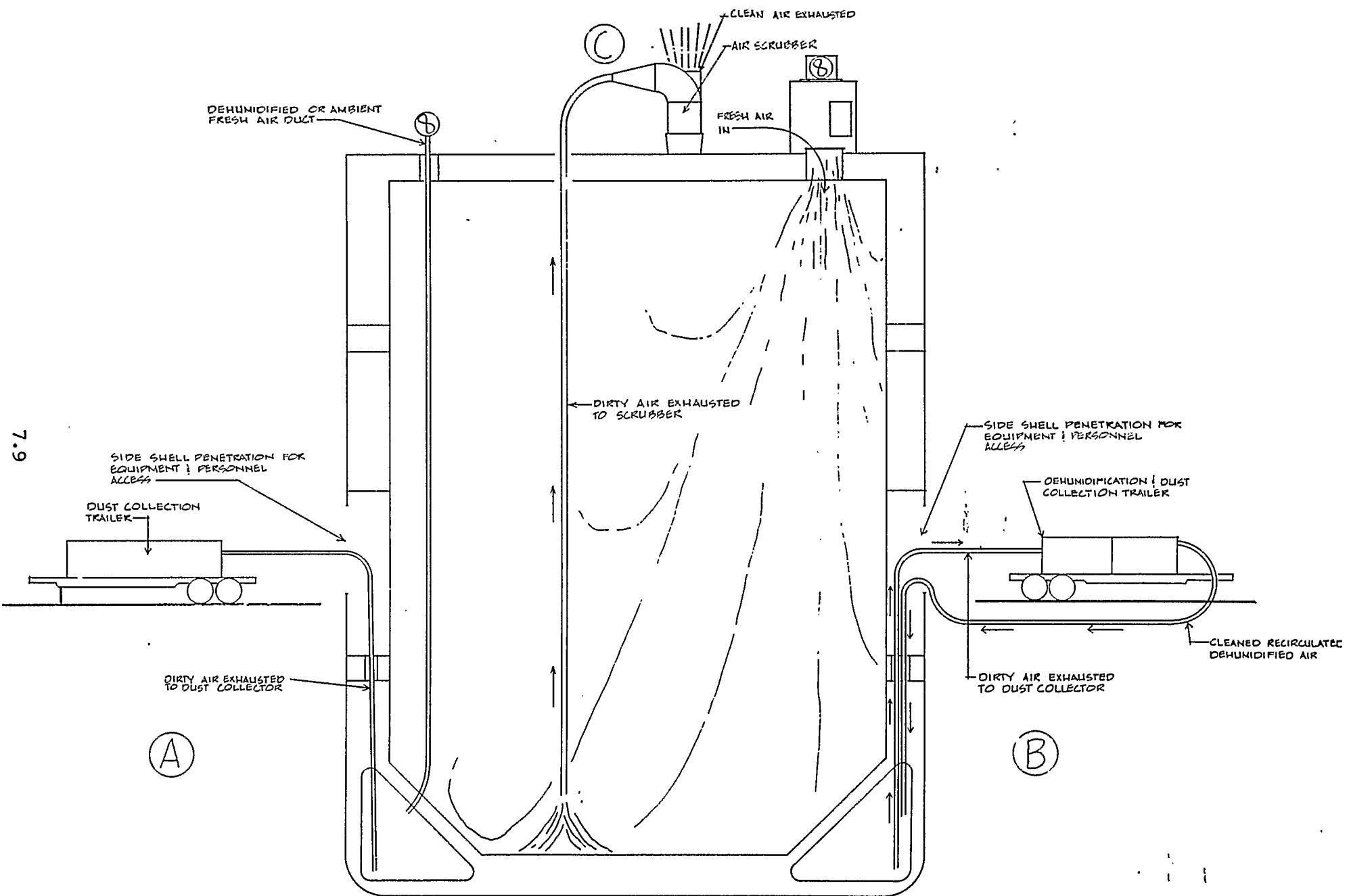


Figure 7.5: Cross Sectional Drawing of a Large Ship Cargo Tank

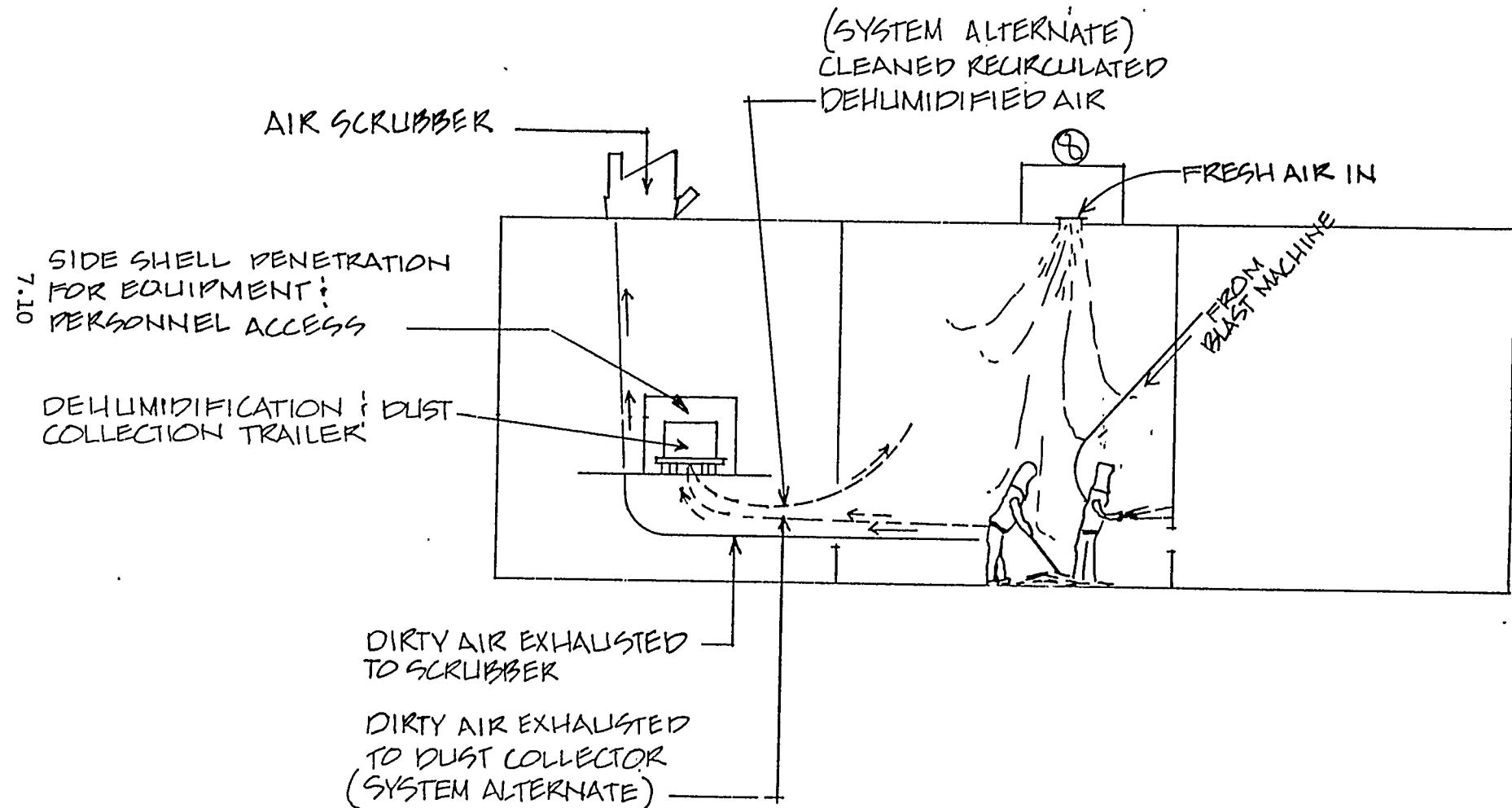


Figure 7.6: Drawing of Ship Tank

ANNEX A

Suppliers List

ANNEX A

SUPPLIERS LIST

Abrasives Suppliers

Cleveland Metal Abrasives, Inc.
305 Euclid Office Plaza, Cleveland, Ohio

Flint Abrasives

Box T-1423, Joplin, Mo., 64801, (417) 623-2424

H.B. Reed and Company, Inc. (Black Beauty)
8149 Kennedy Avenue, Highland, Indiana 46322, (219) 923-4200

Unimin Corporation

50 Locust Avenue, New Canaan, CT. 06840, (203) 966-8880

Wedron Silica Company

400 West Higgins Road, Park Ridge, Illinois 60068, (312) 692-3322

Whitehead Brothers Company

66 Hanover Road, Florham Park, NJ 07932, (201) 377-9100

Abrasive Blasting Equipment Suppliers

Clemco Industries

Jerrols at Upton Street, San Francisco, CA 94124, (415) 282-7290

Complete Abrasive Blasting Systems, Inc. (CAB)

18250 68th Avenue, South, Kent, WA 98031, (206) 226-6012

Empire Abrasive Equipment Corporation

2101 Cabot Blvd., West, Langhorne, PA 19047, (215) 752-8800

Pauli and Griffin

137 Utah Avenue at Wattis Way, South, San Francisco, CA 94080,
(415) 873-4540

Vacublast Corporation

Post Office Drawer 385, Belmont, CA. 94002, (415) 592-2121

Wheelabrator-Frye, Inc.

451 Byrkit Street, Michavaka, Indiana 46544, (219) 255-2141

Compressed-Air Dryers Suppliers

General Air Division Zurn Industries

1335 West 12th Street, Erie, PA. 16501, (814) 453-3651

Pure-Aire, Inc.

Post Office Box 5584, Charlotte, NC 28225, (704) 377-4815

Van Air Systems, Inc.

349 Mechanic Street, Lake City, PA. 16423, (814) 774-2631

Dust Collection Equipment Suppliers

Air Pollution Systems, Inc.

18642 68th Avenue, South, Kent, WA 98031, (206) 251-5330

American Air Filter Company, Inc.

200 Central Avenue, Louisville, KY., 40277 (502) 637-0011

Carter-Day

506 73rd Avenue, NE, Minneapolis, MN. 55432, (612) 571-1000

Torit Division, Donaldson Company, Inc.

1135 Rankin Street, St. Paul, MN 55164, (612) 698-5330

W. W. Sly Manufacturing Company

21945 Drake Road, Strongsville, Ohio 44136, (216) 238-2000

Dehumidification Equipment Suppliers

Bry-Air

Post Office Box 269-T, Sunbury, Ohio 43074, (614) 965-2974

Cargocaire Engineering Company

79 Monroe Street, Amesbury, MA 01913

Drymatic

Airport Industrial Center, Gaithersburg, MD 27760, (301) 948-5000

Kathabar - Medland Ross

Post Office Box 791, New Brunswick, NJ 08903, (201) 356-6000

IRS/International, Inc.

Post Office Box 94, Issaquah, WA 98027, (206) 392-3953

Ducting, Flexible Suppliers

Aeroduct-Porter Company

315 Porter Building, Pittsburgh, PA 15219, (412) 391-100

Anaconda Metal Hose

700 South Main Street, Waterbury, CT 06723, (203) 574-8500

Flexaust

11 Chestnut Street, Amesbury, MA 01913, (617) 388-9700

United McGill Corporation

200 East Broadway, Westerville, Ohio 43081, (614) 882-7401

Fans Suppliers

American Coolair Corporation

P.O. Box 2300, Jacksonville, FL 32203

Aerovent, Inc.

Ash and Bauer Streets, Piqua, Ohio 45356, (513) 773-4611

Cincinnati Fan and Ventilator Company, Inc.

5317 Creek Road, Cincinnati, Ohio 45242, (513) 984-0600

Coppus Engineering

341 Park Avenue, Worcester, MA 01602

Hartzell Propeller Fan Company

910 South Downing Street, Piqua, Ohio 45356, (513) 773-7411

Strobic Air Corporation

207 Bunting Avenue, Trenton, NJ 08611, (609) 396-8216

Vacuum Equipment Suppliers

Central Engineering, Inc. (Vac/All)

4427 State Street, Milwaukee, WI 53209, (800) 558-6944

D.P. Way (Ultra Vac)

Post Office Box 09336, Milwaukee, WI 53209, (800) 558-6944

Key-Houston, Inc.

13911 Atlantic Blvd., Jacksonville, Florida 32225, (904) 241-0633

Super Products (Supersucker)

Post Office Box 27225, Milwaukee, WI 53227

ANNEX B

Selection of Abrasives

ANNEX B

SELECTION OF ABRASIVES

Abrasives are hard, granulated materials which are propelled by compressed air and impacted on the metal surface to remove contamination such as corrosion. Because they are consumed in such large quantities, abrasives represent one of the largest expendable materials costs in the shipyard budget and therefore must be carefully selected and economically utilized.

To obtain the highest cost savings, abrasives selection should be determined by the specific job application. Factors include:

- Size and duration of job (i.e., number of tanks to be cleaned)
- Size and configuration of tank
- Condition of tank surface
- Availability of equipment

These considerations must be matched to the characteristics presented by abrasive materials.

- Physical properties
- Availability
- Performance and safety
- Recyclability

The surface conditions of the tank will determine the coarseness required of the abrasive. Heavily corroded surfaces require a coarser grit material such as U.S. Sieve No. 8-20 (75,000 particles per pound), whereas lighter corroded surfaces require a finer grit material such as U.S. Sieve No. 25-40, (800,000 particles per pound). The following guidelines are important in properly sizing abrasives.

Heavily corroded surface:

- First mechanically descaled are large rust deposits.
- Sand sweeping with coarse abrasive (U. S. Sieve No. 15-30).
- Final blast with medium-sized grit (U. S. Sieve No. 30-45).

Lightly corroded surface:

- Blast with medium-to-fine sized grit (U. S. Sieve No. 30-50)

New and primed steel

- Blast with medium-to-fine sized grit (U. S. Sieve No. 40-70)

The abrasive grit size required for cleaning painted surfaces depends on the type of coating to be removed. Generally, a medium to coarse mix will provide best results.

Abrasive selection for tank surface conditions may be limited by the availability of specific abrasives. Availability, in turn, depends on the location of the shipyard in relation to the source of supply and the market situation.

Performance and safety, in terms of dust generation, blasting production rates, and visibility are directly related to the abrasive physical characteristics, including chemical content, aggregate size, grain shape, hardness and friability (i.e., resistance to shattering).

The recyclability of the abrasive basically depends on friability since this determines how much of the material can be effectively reused.

The following comparisons present the most efficient applications of three types of abrasives, i.e., sand, mineral slag, and steel grit. Cost comparisons are contained in Annex C.

Sand

In the past, sand was the most commonly used material for abrasive blasting. With the determination that silica sand presented a health hazard to workers (silicosis), EPA and OSHA regulations have pressured shipyards to use other types of abrasives. However, with the advent of air-fed helmets for blast operators and dust collection equipment for dust control, the use of sand should be reconsidered as a cost effective abrasive.

Sand is readily available to most shipyards. River and ocean sands are not the best choices for use as abrasives. The ideal type of sand is obtained from a quarry or sandpit. All sands should be properly graded and cleaned prior to purchase. In addition to availability, the greatest advantage of sand is low cost. Savings of from 30 to 100% can be realized by using sand as opposed mineral slag for suitable applications.

Sand abrasives should only be used in enclosed tanks where dust collection equipment and air-fed operator helmets are in operation.

Mineral Slag

As a result of federal legislation promoting the use of non-silica abrasives, mineral slags have become the most commonly used material for shipyard blasting. Because these abrasives are obtained as a by-product of other industries several problems are created for shipyards. These problems include such things as distance to supply sources, transportation, logistics, and unpredictable availability. Many times, the mineral slag supplied to shipyards is not suitable due to non-uniform particle size and high dust content. These conditions result in reduced productivity and increased costs. Although mineral slag abrasives are more costly, no advantage in productivity over sand of similar quality is obtained.

Better grades of mineral slag do offer the possibility of recycling during enclosed tank blasting. The nonavailability of adequate supplies may warrant investment in an automated recovery system. (Refer to Section 6.5)

Generally, slag abrasives are best-suited to external blasting applications such as hull, deck, and superstructure work. These abrasives should also be used for open blasting areas within the yard.

Steel Grit

Steel grit abrasive is more expensive than either sand or mineral slag. This material is supplied in uniform particle size and is dust free. Being steel, the grit is easily contaminated and ruined by water, and great care must be taken that moisture does not enter through tank openings, ventilation equipment or compressed air system.

The principle advantage of steel grit is high resistance to shattering and therefore suitability for recycling. Steel grit can be reused 100 times if properly handled. If steel grit is used in conjunction with dehumidification and compressed air drying to blast small or medium sized tanks, high recyclability can yield substantial savings to the shipyard. See Figures 6.6 and 6.7.

ANNEX C

Abrasive Cost Comparison

ANNEX C

Abrasive Cost Comparison

The following comparisons are based on a blasting operation using 1/2" nozzles at 100 psi and 300 CFM. Under these conditions, each operator will use approximately 1,500 pounds of sand or mineral slag per hour or 4,500 pounds of steel grit per hour. The average delivered cost for one ton each of the following abrasives is.

Sand - \$17.00

Slag - \$40.00

Steel Grit - \$350.00

Sand vs. Mineral Slag

With ten men blasting during an eight hour shift, abrasive consumption would be:

10 men x 1,500 lbs/man/hr = 15,000 lbs

15,000 lbs x 6 hrs actual blast time = 90,000 lbs

90,000 lbs = 45 tons of abrasives used per shift

The cost of sand abrasive would be:

45 x \$17.00/ton = \$765.00 per shift for sand abrasives.

Under the same conditions, the cost of mineral slag abrasives would be:

45 tons x \$40.00/ton = \$1,800.00 per shift for mineral slag.

Cost difference for one eight hour shift would be:

\$1,800 - \$765 = \$1,035

With a conservative assumption of 250 days a year of blasting:

$$250 \times \$1,035 = \$258,750.00 \text{ cost difference per year.}$$

This figure represents the possible yearly savings in abrasives costs if sand were used in lieu of slag. The money saved could be used to purchase all or most of the dust collection equipment required when using sand abrasives.

Non-recycled Slag vs. Steel Grit

Calculating abrasive costs per year and assuming six man-hours per day and 250 blasting days per year,

$$6 \text{ hrs} \times 250 \text{ days} = 1,500 \text{ man hours (M.H.) of blasting per year per operator}$$

At a consumption rate of 1,500 /lbs/M.H. for slag abrasives,

$$1,500 \text{ lbs} \times 1,500 \text{ M.H.} = 2,250,000 \text{ lbs per operator}$$

$$\frac{2,250,000}{2,000} = 1,125 \text{ tons of slag per year for each operator.}$$

At a consumption rate of 4,500 lbs/hr for steel grit,

$$4,500 \text{ lbs/hr} \times 1,500 \text{ M.H. per year} = 6,750,000 \text{ lbs per operator}$$

$$\frac{6,750,000 \text{ lbs}}{2,000} = 3,375 \text{ tons of steel grit per year.}$$

If properly utilized however, steel grit can be recycled up to 100 times (cycles), thus:

$$\frac{3,375 \text{ tons}}{100 \text{ cycles}} = \text{approx. 34 tons of steel grit per year per operator.}$$

Cost per year for slag would be:

$$1,125 \text{ tons/yr} \times \$40/\text{ton} = \$45,000.00 \text{ per operator}$$

Cost of steel grit for actual consumption would be:

$$34 \text{ tons/yr} \times \$350/\text{ton} = \$11,900 \text{ per operator}$$

Possible yearly savings in abrasives costs of using steel grit over non-recycled slag, then are:

$$\$45,000 - \$11,900 = \$33,000 \text{ yearly cost difference per operator}$$

Calculating abrasive cost per square foot of cleaned surface, and assuming 200 square feet can be blasted by one operator in one hour:

$$200 \text{ sq. ft.} \times 1,500 \text{ man/hrs per year} = 300,000 \text{ sq. ft. per man per year}$$

Cost per square foot for slag abrasives would be:

$$\frac{\$45,000/\text{yr}}{300,000 \text{ sq. ft.}} = \$0.15 \text{ per sq. ft. for slag.}$$

Steel grit costs per square foot of blasted surface would be:

$$\frac{\$11,900/\text{yr}}{300,000 \text{ sq. ft.}} = \text{approx } \$0.04 \text{ per sq. ft. for steel grit.}$$

In conclusion, three 1/2" nozzles using steel grit will produce 900,000 sq. ft. of cleaned surface at a cost of \$35,000 per year while an equal area blasted with non-recycled slag will cost \$135,000. The yearly cost difference of \$100,000 does not include costs of slag disposal or those incurred in recycling the grit.

Recycled Slag

In this example an assumption was made that the abrasive will be recovered from an enclosed tank and will be dry and easily collected. Under these conditions, slag could be collected into large vacuum recovery tanks. Since the removal of the spent abrasive from the tank internal is required in any event, no cost has been assigned to removal for the purpose of evaluating the economics of recycling. The same holds true for the disposal from the collection tanks into a vehicle which would either transport the material to a disposal area or to a recycling center. Therefore, the costs associated with recycling are basically those of the fixed plant and the operator.

If abrasive costs \$40 per ton and one operator uses 1,500 pounds per hour, the cost of slag will be:

$$\frac{1,500 \text{ lbs}}{2,000} = \$.75 \text{ tons}$$

$$\$40/\text{ton} \times .75 = \$30 \text{ per M.H.}$$

With a good mineral slag abrasive, approximately 60% of the original material may be used a second time and 30% of this twice-used abrasive may be used still a third time. Thus, each ton of, new recyclable abrasive (reused twice) is the equivalent of 1.78 tons.

$$(1.0 \times 1) + (1.0 \times 0.5) + (0.6 \times 0.3) = 1.78.$$

Recycling can effectively reduce the abrasive costs from \$40.00 per ton to:

$$\frac{\$40}{1.78} = \$22.47 \text{ per ton (three passes).}$$

On the second pass, 60% of the original slag is reused:

$$1,500 \text{ lbs/M.H.} \times .6 = 900 \text{ lbs/M.H. which is recycled}$$

This recycled slag equates to

$$\frac{900 \text{ lbs}}{2,000} = .45 \text{ tons/M.H.}$$

On the third pass, 30% of the 2nd pass slag is reused.

$$900 \text{ lbs/M.H.} \times .3 = 270 \text{ lbs/M.H.}$$

$$\frac{270 \text{ lbs}}{2,000} = .135 \text{ tons/M.H.}$$

These figures may also be used to determine the economic value of recycling good-quality spent abrasives already in the shipyard. Each ton that is recycled for a second pass is worth:

$$.6 \times \$40 = \$24.00/\text{ton},$$

and each ton when recycled for a third pass is additionally worth:

$$.6 \times .3 \times \$35.00 = \$7.20/\text{ton}.$$

Therefore, the total value (or savings) available from recycling the existing spent abrasive is:

$$\$24 + \$7.20 = \$31.20/\text{ton of once-used material}$$

If a yard has ten men blasting tank internals for one shift, 250 days per year, then the total amount of abrasive required would be:

$$10 \text{ men} \times 6 \text{ hrs blast time per day} \times 250 \text{ days/yr} = 15,000 \text{ M.H. per year}$$

$$15,000 \text{ M.H.} \times 1,500 \text{ lbs/M.H.} = 22,500,000 \text{ lbs.},$$

or 11,250 tons per year.

If we assume all new abrasive:

$$11,250 \text{ tons/yr} \times \$40/\text{ton} = \$450,000 \text{ per year for abrasives}$$

If a recycling plant is added:

On the second pass, each ton of new abrasive is used.

$$1.0 + .6 = 1.6 \text{ times}$$

This reduces the cost of abrasives to:

$$\frac{11,250 \text{ tons}}{1.6} = 7,032 \text{ tons} \times \$40/\text{ton} = \$281,250 \text{ per year.}$$

Thus the abrasive savings from a first stage of recycling is:

$$\$450,000 - \$281,250 = \$168,750 \text{ yearly savings.}$$

These savings would be doubled if two shifts were operating per day, and would increase proportionately with the number of blasters.

With a third pass, each ton of new abrasive is used:

$$1.0 + .6 + (.3 \times .6) = 1.78 \text{ times.}$$

This further reduces the total abrasives costs to:

$$\frac{11,250 \text{ tons}}{1.78} = 6,320 \text{ tons} \times \$40/\text{ton} = \$252,809 \text{ per year.}$$

The total abrasive savings from recycling becomes:

$$\$450,000 - \$252,809 = \$197,191 \text{ yearly cost savings.}$$

If the yard has an existing pile of spent (once-used) abrasives containing 10,000 tons of recyclable material, this slag may also be reused to further

reduce the new abrasives required in the first year of the recycling plant's operation. With recycling, this material represents:

$$.6 \times (.3 \times .6) = .78 \text{ tons}$$

$$.78 \times 10,000 = 7,800 \text{ tons of usable abrasive.}$$

This additional savings amounts to:

$$7,800 \text{ tons} \times \$40/\text{ton} = \$312,000 \text{ for the first year.}$$

If the yard has large quantities of spent material on hand which are suitable for recycling, abrasive replenishment may not be needed for a long time.

The total possible savings for abrasive materials with the use of an abrasive recycling system in the above example would be:

$$\text{first year: } \$197,191 + \$312,000 = \$509,191$$

$$\text{second and succeeding years: } \$197,191 \text{ per year.}$$

With the initial cost of an abrasive recycling plant ranging from \$25,000 to \$600,000, the plant could pay for itself during the first year with abrasive cost savings.

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